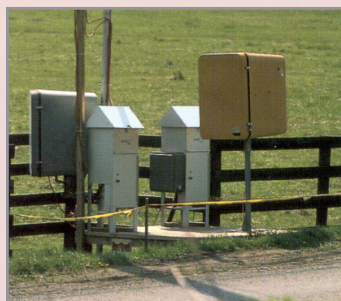




Massachusetts Port Authority Logan International Airport

Air Quality Monitoring Study Final Air Quality Work Plan

September 2007



EMORY
UNIVERSITY



Final Work Plan

Massachusetts Port Authority
Logan International Airport
**Air Quality Monitoring Study
Final Work Plan**

September 2007

Work Plan

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Executive Summary

As part of the Massachusetts Environmental Policy Act (MEPA) Certificate on the *Final Environmental Impact Report* (EIR) for the Logan Airside Improvements Project (LAIP), the Secretary of the Executive Office of Environmental Affairs (EOEA) has called for an air quality study (the *Logan International Airport Air Quality Monitoring Study*). The purpose of the Study is to monitor air quality conditions (with a focus on “air toxics”) in the vicinity of Logan International Airport (Logan) in advance of, and following, the implementation the new Centerfield Taxiway. The Centerfield Taxiway is one of the primary components of the LAIP.

This document contains the final *Work Plan* for conducting the Study and reflects the consultative process with the Massachusetts Departments of Public Health (MADPH) and Environmental Protection (MADEP), also called for in the MEPA Certificate. This Study will be completed by the Massachusetts Port Authority (Massport), the owner and operator of Logan, and the primary components of the Work Plan comprise the following:

Monitoring Sites

Because the monitoring site locations can directly affect the utility and representativeness of the collected data, several key considerations were made in their selection, including:

- Consistency with the MEPA Certificate as being under (or near) the airport flight paths and in neighborhoods surrounding Logan;
- Distance and direction from the Centerfield Taxiway;
- Prevailing wind directions, other nearby sources of emissions; and site access and security.

Based upon these criteria, coupled with input from MADPH/MADEP, three “primary” sites have been established that will comprise both “active” and “passive” air monitoring methods specifically selected for this Study. In addition, Massport has elected to add seven “satellite” sites and one urban background site located nearby that will utilize primarily passive samplers. The urban background site will be located at the MADEP Harrison Avenue site. This approach enables the collection of appropriate data in a scientifically acceptable and cost-effective manner over an extended study area.

Target Pollutants

Air toxics (also known as hazardous air pollutants or “HAPs”) are emitted from a variety of emission sources, both natural and man-made. Therefore, the Target Pollutants for this Study are specifically selected as they represent the primary forms of combustion products or evaporative emissions from airport related sources. They include:

- Volatile Organic Compounds (VOCs);
- Carbonyls (e.g., formaldehyde);
- Semi-volatile Organic Compounds (SVOCs) / Polynuclear Aromatic Hydrocarbons (PAHs);
- Particulate matter; and
- Black Carbon.

Although not classifiable as HAPs by the U.S. Environmental Protection Agency (EPA), particulate matter (PM) and black carbon (BC) serve as indicators (or “surrogates”) to the presence of fuel combustion products. Moreover, both PM and BC are pollutants of concern to MADEP/MADPH and the general public, alike.

Monitoring Methods

As mentioned above, the air monitoring methods for this Study are subdivided into two general categories: active and passive. Both continuous (or “real-time”) and time-integrated techniques are included. This combined (or “hybrid”) approach to the Study blends together the benefits of all these monitoring methods, thus allowing for expanded coverage both spatially and temporally.

Importantly, the primary sites will utilize monitoring methods that have been compiled by EPA as representing the best elements of peer-reviewed, standardized methods for the determination of toxic organic compounds in ambient air.

Data Analysis and Reporting

Air monitoring will be conducted over two separate one-year periods. Combined with the meteorological and other supporting data, a vast amount of information will be collected and assessed. To distill this material into meaningful information, the data will be assimilated into summary statistics that are intended to give the reviewers a comprehensive, yet concise, interpretation of the findings. The air monitoring data will be compared to standards, as appropriate. In addition, the air monitoring data will be compared to measurements obtained from nearby MADEP monitoring sites.

Upon completion of the data quality review and data analyses, quarterly and summary reports will be prepared covering each 12-month monitoring period. These reports will be made available to MADEP, MADPH and the public through the annual EDR/ESPR process.

Schedule

The Study will take place over the next five years and over two distinct phases: an initial “baseline” monitoring period and a “follow-up” monitoring period. Each period is expected to last approximately 12 months. Planning and preparations for the baseline phase are currently underway and baseline monitoring is expected to begin in the summer of 2007. The Centerfield Taxiway construction will occur over a two-year period beginning in 2008 and be completed in 2010. Following the completion of the Centerfield Taxiway construction, the follow-up monitoring program will be performed.

Section 1

Introduction

This document represents the final Work Plan for conducting the *Logan International Airport Air Quality Monitoring Study* (Study). This final document includes revisions based on written comments received by the Massachusetts Departments of Public Health (MADPH) and Environmental Protection (MADEP) on the draft version of the Work Plan, dated February 2007, and additional consultations with each agency. A copy of the MADEP/MADPH memorandum and response to comments is presented in **Appendix F**.

The Study is required by the Secretary of the Executive Office of Environmental Affairs (EOEA) in a Massachusetts Environmental Policy Act (MEPA) Certificate on the Final Environmental Impact Report (EIR) for the *Logan Airside Improvements Project (LAIP)*¹. Briefly stated, the Study is comprised of a monitoring program designed to measure air quality conditions (with a focus on “air toxics”) under (or near) the flight paths and in the neighborhoods surrounding Logan International Airport (Logan). The Study will be completed by the Massachusetts Port Authority (Massport), which owns and operates Logan.

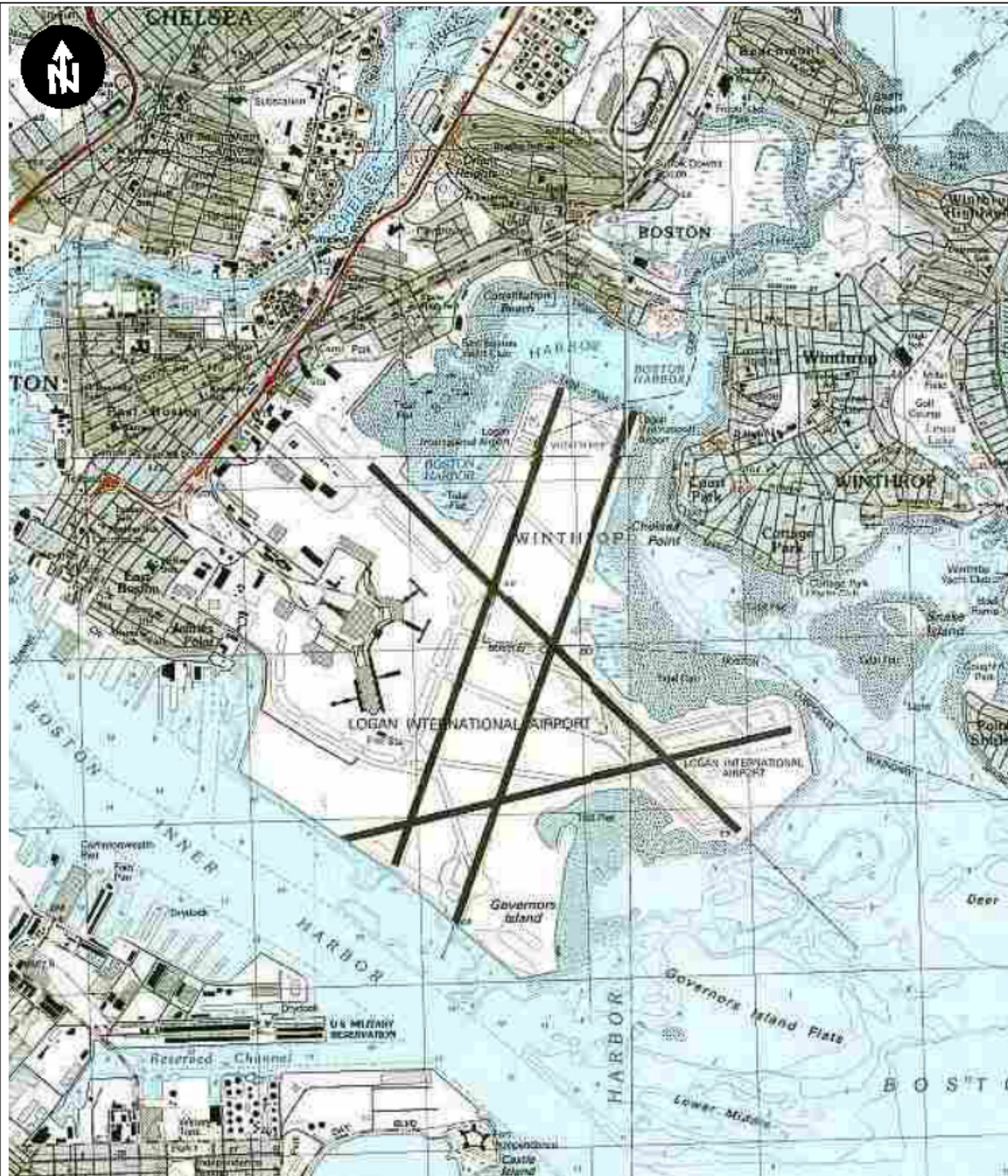
Within the sections that follow, the Study objectives are clearly defined, the overall approach to completing the assessment is discussed, and the technical elements of the monitoring program are presented. The *Appendices* contain additional information collected and prepared in support of the Work Plan. Summarized below is further information on Logan, the LAIP, and the MEPA Certificate as it pertains to the Study.

1.1 MEPA Certificate and Study Overview

Logan is New England’s largest transportation center and occupies approximately 2,400 acres in East Boston, Massachusetts (see **Figure 1-1**). In 2005, Logan ranked as the 20th busiest airport in the U.S. based on volume of over 27 million passengers. The airfield contains six runways (i.e., 4R/22L, 4L/22R, 15R/33L, 15L/33R, 9/27 and 14/32); associated taxiways, aprons and terminal facilities, and is surrounded by Boston Harbor and the communities of East Boston, South Boston, and Winthrop.

On June 15, 2001, the EOEA Secretary issued a MEPA certificate on the LAIP Final EIR. The LAIP serves as the blueprint for a series of improvements to Logan over several years. One important component of the LAIP is the Centerfield Taxiway, a new 9,300-foot taxiway to be constructed between existing runways 4R/22L and 4L/22R.

¹ Massachusetts Executive Office of Environmental Affairs, *Certificate of the Secretary of Environmental Affairs of the Final Environmental Impact Report*, Logan Airside Improvements Planning Projects, June 15, 2001.



Scale: 1:25000

Source: USGS 1:25000 Scale Topographic Maps
scanned images by MassGIS - July 1996

Massport
Boston, Massachusetts

Figure 1-1
Logan International Airport

In response to concerns of residents in communities surrounding Logan about potential adverse air quality and odor impacts, the EOEa Secretary issued the following condition in the MEPA certificate with respect to the Centerfield Taxiway.

MEPA Certificate Centerfield Taxiway Air Monitoring Study

“[I]n addition, within the ESPR process Massport shall conduct follow-up air quality monitoring in neighborhoods surrounding the airport and under the flight path of Logan Airport. This information will be shared with the Department of Public Health (DPH) and reported in the ESPR update, to provide baseline data for future studies. Massport should consult with DEP and DPH in developing an air quality monitoring protocol using periodic air sampling in residential areas with a special focus on air toxics. Massport should also complete within the next five years a special air toxics monitoring study that will include a public meeting to discuss the results.”

Massport anticipates that the Study will take place over the next five years (2007-2011) and air monitoring will be performed over two distinct periods: an approximate 12-month baseline period and an approximate 12-month follow-up period. Massport also expects that the data will be used for future studies by the MADPH and MADEP, or others. Importantly, in its current design the Study does not include any health effects or risk analyses, nor does it evaluate the interpretation of airport and non-airport emissions. Massport will implement a program to present the results of the Study and to help engage local stakeholders in issues related to air quality around Logan.

1.2 Existing Air Quality

To protect the public health and welfare, the U.S. Environmental Protection Agency (EPA) has promulgated national ambient air quality standards (NAAQS) for the following seven air pollutants, referred to as criteria pollutants: carbon monoxide (CO), ozone (O₃), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), particulate matter with an equivalent aerodynamic diameter of 10 micrometers (PM₁₀), particulate matter with an equivalent aerodynamic diameter of 2.5 micrometers (PM_{2.5}), and lead (Pb). MADEP has also adopted these standards.

Logan is located in the Metropolitan Boston Intrastate Air Quality Control Region (AQCR) which includes the City of Boston and its outlying suburbs.² As shown in **Table 1-1**, this area is presently designated by EPA as being in “attainment” with all

² Beverly, Boston, Brockton, Cambridge, Chelsea, Everett, Gloucester, Lynn, Malden, Marlborough, Medford, Melrose, Newton, Peabody, Quincy, Revere, Salem, Somerville, Waltham, Woburn.

of the NAAQS with the exception of CO and O₃; for which it is designated as “maintenance” and “non-attainment,” respectively³.

Table 1-1 Attainment/Non-Attainment Designations For Metropolitan Boston	
Pollutant	Designation
Carbon Monoxide	Maintenance
Lead	Attainment
Nitrogen Dioxide	Attainment
Ozone (8-hour)	Non-attainment
Particulate Matter (<10 microns)	Attainment
Particulate Matter (< 2.5 microns)	Attainment
Sulfur Dioxide	Attainment

Source: U.S. EPA, 2007.

While there are no NAAQS for toxic air pollutants similar to those for criteria pollutants, MADEP has developed Allowable Ambient Limits (AALs) for source permitting purposes. However, these AALs are not directly comparable to monitored levels of these pollutants.

As part of its state-wide air monitoring network, MADEP operates an air monitoring station on Harrison Avenue in Roxbury, approximately 4 miles southwest of Logan. This is the closest urban-scale monitoring station to the airport, is located in an urban setting and is used to monitor the EPA criteria pollutants as well as a variety of toxic air pollutants. MADEP also operates a similar air monitoring station in Lynn, approximately 7.5 miles north-northeast of Logan and in a more rural setting. A third station was located on Bremen Street adjacent to the airport, but it was closed a few years ago.

Notably, Massport has continually monitored ambient levels of nitrogen dioxide (NO₂) for over 24 years at numerous locations both on and off airport property⁴. The findings from that program reveal that NO₂ levels in the vicinity of the airport are

³ Attainment means there are no recorded exceedances of the NAAQS in the area; non-attainment means exceedances of the NAAQS have occurred in the area; and maintenance means the area is in transition on from non-attainment to attainment.

⁴ 2005 Environmental Data Report, Boston-Logan International Airport, December 2006.

well below federal and state standards and these levels are continually declining. In another initiative, Massport collected samples of atmospheric fall-out (e.g., soot) from sites on the airport and in the surrounding neighborhood.⁵ The results of that study showed that the contribution from airport-related emission sources was very small and virtually indistinguishable from other, non-airport sources.

⁵ 1996, Logan Airport Soot Deposition Study, Prepared for Massport by KM Chng Environmental, November, 2006.

Section 2

Study Objectives

2.1 Introduction

Based on the MEPA Certificate for the LAIP Centerfield Taxiway, Section 1.1 of this Work Plan discussed the overriding purpose, or intent, for conducting air quality monitoring at Logan. For ease of reference, the MEPA Certificate excerpt calling for the Study is restated below.

MEPA Certificate Centerfield Taxiway Air Monitoring Study

“[I]n addition, within the ESPR process Massport shall conduct follow-up air quality monitoring in neighborhoods surrounding the airport and under the flight path of Logan Airport. This information will be shared with the Department of Public Health (DPH) and reported in the ESPR update, to provide baseline data for future studies. Massport should consult with DEP and DPH in developing an air quality monitoring protocol using periodic air sampling in residential areas with a special focus on air toxics. Massport should also complete within the next five years a special air toxics monitoring study that will include a public meeting to discuss the results.”

This section identifies and describes the specific objectives of the Study - the importance of which cannot be overstated as they form the guiding principles upon which the Work Plan is designed. These principles include the locations of air monitoring sites, the selection of the pollutants analyzed and the monitoring or sampling methods employed.

2.2 Understanding the MEPA Certificate Pertaining to the Air Quality Monitoring Study

The MEPA Certificate contains four statements that reveal the intended scope of the Study. These are restated below (*in italics*) followed by explanations of how they are incorporated within this Work Plan.

- a. *Within the ESPR process Massport shall conduct follow-up air quality monitoring in neighborhoods surrounding the airport and under the flight path of Logan Airport.*

In this context, the term *follow-up air quality monitoring* is taken to mean air monitoring following the implementation of the Centerfield Taxiway. The expression *in neighborhoods surrounding the airport and under the flight path* is interpreted to comprise areas in Winthrop, East Boston, and South Boston that are closest to the airport and under (or near) the arrival and departure tracks for in-bound and out-bound aircraft.

- b. *This information will be shared with the Massachusetts Department of Public Health (MADPH) and reported in the ESPR Update, to provide baseline data for future studies.*

It is understood that Massport will report on the Study in the annual EDR/ESPR documents and the collected data will be provided to the MADPH/ MADEP¹. The term *baseline data* is taken to mean the data collected before the implementation of the Centerfield Taxiway. The reference to *future studies* means the follow-up air monitoring discussed under item “a”, above.

- c. *Massport should consult with MADEP and MADPH in developing an air quality monitoring protocol using periodic air sampling in residential areas with a specific focus on air toxics.*

From this, it is understood that Massport will develop an approach for conducting the Study and consult with MADEP/ MADPH on the approach and its implementation. The term *protocol* is taken to include this Work Plan as well as the Quality Assurance Project Plan (QAPP). The term *periodic air sampling* is taken to mean air sampling (or monitoring) on a temporal (i.e., seasonal, monthly, weekly and/or daily) basis that will best evaluate air toxics in the vicinity of the airport. The term *residential areas* includes the same neighborhoods mentioned above under item “a”. Finally, the term *air toxics* is considered to be synonymous with toxic air pollutants (TAPs) and hazardous air pollutants (HAPs), but may also include particulate matter and/or black carbon as potential indicators (or “surrogates”) of fine PM and jet exhaust.

- d. *Massport should also complete within the next five years a special air toxics monitoring study that will include a public meeting to discuss the results.*

Based on this statement, it is understood that the entire Study must be completed in the next five years and the results will be presented to the general public. The term *special air toxics monitoring study* is understood to mean the Study outlined in this Work Plan. The term *public meeting* is taken to mean a forum, announced in advance and planned for a certain time and place, where the public has the opportunity to review, ask questions, and discuss the Study findings.

This information is used as the framework for formulating the objectives for this Study which are sub-divided below into Primary and Supporting Objectives.

2.3 Primary Objective

As a means of focusing and simplifying the Work Plan, the Primary Objective of the Study has been summarized into one sentence, as follows:

¹ EDR/ESPR – Boston Logan International Airport Environmental Data Report/Environmental Status Progress Report.

Primary Objective

Collect air quality data with an emphasis on air toxics under (or near) the flight paths and in the neighborhoods surrounding Logan International Airport in advance of, and following, the implementation of the Centerfield Taxiway.

This simple and direct understanding of the MEPA Certificate's intent facilitates the formulation of the Work Plan, enables the work to fully address the specific aims of the Study, and increases the likelihood that the program will reach successful completion.

2.4 Supporting Objectives

From the MEPA Certificate, it is clear that there are other particular elements to the air monitoring program that are considered necessary (bulleted ("•") under *MEPA Certificate* below). These include consultation with MADPH/MADEP, sharing and reporting of collected data, and a timeframe for completing the Study.

Some early comments on the proposed Study from MADEP, MADPH, and members of the community surrounding Logan (bulleted under *MADPH, MADEP, and Community Comments* below) are also potentially important.^{2,3,4} These include definitive timeframes for conducting the monitoring and suggestions on the monitoring methods.

Added to these are several features (bulleted under *Other Considerations* below) of any investigation of ambient air quality conditions that are regarded as essential to achieving a successful outcome. These factors are particularly applicable when measuring toxic air pollutants that are emitted from many and varied sources. Such considerations include the use of reliable and cost-feasible methods; efficient use of funds and resources; and the ability to evaluate the findings properly based on the potential uncertainties, limitations, and unforeseen events that are inherent to this type of investigation.

For clarity and simplicity, these supporting objectives are restated below as one-sentence summaries.

²Massachusetts Department of Public Health (MADPH), Meeting with MADPH, CDM, Emory University and Massport, Toxic Air Pollutant Monitoring Plan Development for Logan Airport, February 10, 2006.

³Massachusetts Department of Environmental Protection (MADEP), Meeting with MADEP, CDM, Emory University and Massport, Air Toxics Monitoring Program at Logan International Airport: Background and other Studies. February 28, 2006.

⁴Flavin, A., *A Neighborhood Representative's Perspective on the Proceedings of the Centerfield Taxiway Evaluation Committee and Recommendations for Environmental Fairness for the People of Winthrop and East Boston*, May 18, 2006.

Supporting Objectives

----- MEPA Certificate ----

- *Consult with MADPH and MADEP on the preparation of the Air Quality Protocol.*
- *Share the collected baseline data with MADPH for future studies.*
- *Provide information of the program in the annual EDR/ESPR documents.*
- *Complete the study within five years.*
- *Hold a meeting for the public to review and discuss the findings.*

----- MADPH, MADEP, and Community Comments -----

- *Collect one year of data in advance, and following the implementation, of the Centerfield Taxiway.*
- *Perform “real-time” measurements.*
- *Discuss scientific findings in terms that are comprehensible to lay-persons.*

----- Other Considerations -----

- *Use reliable and scientifically proven monitoring methods including both active (i.e., using a pump) and passive (i.e., not using a pump) techniques that allow for multiple locations and extended periods of monitoring.*
- *Monitor compounds that are representative of airport-related emission sources.*
- *Select monitoring sites that are feasible and secure for data collection.*
- *Use general findings from air monitoring studies already completed or under way at other airports and specific local monitoring data collected by MADEP.*
- *Identify and evaluate possible cause(s) of data trends, outliers, and other findings.*
- *Identify and evaluate potential effects on data from meteorology, temporal, and spatial influences.*
- *Allow for adjustments and other changes to the Work Plan as the monitoring program progresses and data become available.*
- *Identify and evaluate potential impacts on data from airport-related and non-airport related emission sources.*
- *Identify and evaluate both the strengths and weaknesses of the air monitoring program.*

Although these objectives are termed as “Supporting” they are neither treated nor looked upon in this Work Plan as incidental or less important. Rather they are segregated and presented separately so as not to distract from the Primary Objective.

The approach and methodology for accomplishing the objectives of the Study are discussed in the following sections.

Section 3

Technical Approach Overview

This section summarizes the overall technical approach for conducting the Study and addresses several important considerations such as the choice and locations of air monitoring sites, the selection of the pollutants analyzed and the monitoring or sampling methods to be used. Notably, the development of this approach relies heavily on input from MADEP/MADPH, the prior experiences of the Project Team in this highly specialized field as well as the outcomes of similar air monitoring programs conducted at other airports both in the U.S. and abroad.

3.1 Monitoring Sites

The identification, evaluation and selection of the monitoring sites are among the most important elements of the Study. This process involves several key considerations that can have direct and significant effects on the utility of the data collected and the overall success of the program. The most significant of these factors are briefly discussed below.

3.1.1 Evaluation Criteria

For this assessment, relevant information for each potential site was obtained from several sources including the review of up-to-date aerial photography, maps and charts of the airport and surrounding areas; on-line computer searches of sites and addresses; consultations with Massport, MADEP/MADPH and FAA staffs; and in-the-field site visits by the Project Team. This information was assessed using the following criteria:

- *MEPA Certificate Requirements* – In keeping with the Primary Objective of the Study, potential monitoring site locations were evaluated with respect to the inbound and outbound flight tracks as well as their proximity to residential neighborhoods surrounding the airport. Sites that are characterized as being both residential and near the flight paths, with those located closest to the airport, are of greatest potential interest.
- *Distance and Direction from the Centerfield Taxiway* – Because the primary aim of the Study is to monitor the potential effects of the Centerfield Taxiway on air quality conditions, the distances and directions from this new facility to the candidate monitoring sites were considered. In this analysis, it is given that the new taxiway will be located midway between Runways 4L/22R and 4R/22L and the shortest straight-line measurements were used. Sites located one mile away or closer to the Centerfield Taxiway are of more interest than those further away.
- *Nearby Emission Sources & Other Potential Influences* – Logan is located in an urban area characterized by a wide assortment of other emission sources including motor vehicle surface traffic, railroads, ships and other marine port activities;

home heating units; industry and power generation. All of these were considered as potential influences on data collected from any of the candidate sites.

- *Meteorological Conditions* – Although wind direction and speed in the vicinity of Logan vary throughout the year, some consistent patterns occur. Wind direction and wind speed data collected at Logan International Airport over a representative five year period (1991-1995) was used to develop wind roses (i.e., wind frequency distribution data) to determine seasonal and annual wind patterns. For example, in the winter months the winds are predominately from the WNW varying to the SW with an average speed of 14 miles per hour (mph) and few calm periods. In the summer months the prevailing winds switch direction and are mostly from the SW varying to the WNW with an average speed of 11 mph and more frequent calm periods. (During the spring and fall months the winds are generally in transition between the NW and SW.) From this information, “down-wind” locations from the airport are mostly to the E and SE (i.e., Winthrop, Boston Harbor, Deer Island and Port Shirley) in winter and to the E and NNE (i.e., Winthrop and E. Boston) in summer. For this assessment, monitoring sites in neighborhoods that are located generally downwind of the airport are of greatest potential interest.¹
- *Site Ownership, Accessibility and Security* – Air quality sampling involves monitoring equipment, devices and various other apparatus that require shelter from the elements, routine maintenance and security from vandalism. Some of the equipment is sensitive to disturbance and costly. Therefore, the property owner, ease of access and other safeguards are important considerations. In locations where access is limited due to security concerns, FAA involvement also becomes a factor.
- *Other Factors and Considerations* – Several other potentially important factors were also considered in the identification, evaluation and selection of air monitoring sites. For example, the availability of a building to house and electricity to power the equipment are two practical considerations. The availability of the site in the immediate term and over the next five years was also considered. Other factors considered include the proximity of the ongoing Massport NO₂ monitoring sites and the soot monitoring locations from 1996.² Finally, areas around the airport historically experiencing odor complaints were evaluated and particular notice was given to runway landing / take-off events as well as areas located closest to ground-based operations (i.e., taxi-in, taxi-out and queues).

These factors are listed in Table 5-1 (Summary of Logan Airport Air Monitoring Site Evaluation) to help identify the likely attributes and possible drawbacks of each

¹ Appendix B contains a summary of wind speed and direction data based on five years of meteorological observations at Logan Airport.

² Appendix C contains maps showing the locations of the soot and NO₂ monitoring sites around Logan Airport.

potential site with the goal of selecting sites that offer the best opportunities for meeting the Primary and Supporting Objectives of this monitoring program.

3.1.2 Criteria Ranking

For ease in assimilating this information, the evaluation criteria are generally arranged in descending order of importance and are ranked “good”, “marginal” or “problematic” based on their relative degree of acceptability. The site evaluation criteria rankings are summarized in **Table 3-1**.

Table 3-1 Site Evaluation Criteria Rankings			
Evaluation Criteria	Site Ranking		
	Good	Marginal	Problematic
MEPA Requirements 1. Neighborhood 2. Residential 3. Under Flight Path	All	Two	One or None
Distance/Direction to Centerfield Taxiway	1 mile or less	Less than 2 miles	2 miles or more
Nearby Emissions Sources & Influences, except Airport	None	Some (e.g., local traffic)	Numerous (e.g., port activities)
Upwind/Downwind	Downwind Winter & Summer	Upwind and/or Neutral Winter & Summer	Neutral Winter & Summer
Property Ownership	Massport	Municipal	Private
Security/Vandalism	Secure location	Some security, poss. Vandalism	Low security
FAA Involvement	No	Possible	Yes
Road Access	Readily Accessible	Not Easily Accessible	None
Shelter or Existing Building	Climate Controlled Existing Building	Non-Climate Controlled Existing Building	Shelter Required
Electricity Available	Readily Available	Not Readily Available	None
Site Availability (short- and long-term)	Available in short- and long-term	Only available either short- or long-term	Not available
Soot and NO ₂ Monitoring Location (Passive Sites)	Yes: Good passive monitoring site	Possible: Adjacent to soot or NO ₂ monitoring site	No: Not located near soot or NO ₂ monitoring site
Percentage of Time Under Flight Path	Greater than 50 percent	30 to 50 percent	Less than 30 percent

The monitoring sites and the basis for their selections are discussed in Section 5.

3.2 Target Pollutants

The MEPA Certificate states that the Study place “a special focus on air toxics.” Toxic air pollutants, also referred to as HAPs, include a broad range of pollutants (i.e., organic and inorganic gases, aerosols and particles) for which there are no NAAQS. However, under the federal the Clean Air Act (CAA), EPA currently recognizes and regulates a total of 188 compounds (or compound categories) as HAPs.

3.2.1 Background Information

HAPs are emitted from a variety of emission sources, both natural and anthropogenic. Within the environs of a commercial airport, such as Logan, categories of HAPs emission sources can include “stationary point” sources (e.g., boilers, back-up generators, fuel facilities), “area” sources (e.g., fire training and construction activities), “on-road mobile” sources (e.g., cars, vans, buses), and “nonroad mobile” sources (e.g., aircraft, ground support equipment (GSE), auxiliary power units (APUs), and snow removal and melting equipment).

Because the products of combustion from airport-related sources are so similar to those from sources present in an urban area (e.g., motor vehicles traveling on the surface roadway network, power plants and other industries, home heating units, etc.) it has proven difficult to differentiate these sources of HAPs from one another. In other words, HAPs emitted from sources on an airport are essentially identical to those emitted from the myriad sources off the airport.

The majority of HAPs derived as products of combustion or released as evaporative emissions from fuel are generally classifiable into three categories, as briefly discussed below:

- *Volatile Organic Compounds (VOCs)* – These pollutants are either gaseous or may readily volatilize at ambient (e.g., outdoor) conditions due to their high vapor pressures. The list of VOCs is extensive but some of the more common species include benzene, ethylbenzene, toluene, xylenes and 1,3-butadiene.
- *Carbonyls* – These pollutants are similar to VOCs but are more chemically reactive at ambient conditions. The category of carbonyls comprises several sub-categories such as aldehydes (e.g., acetaldehyde, acrolein, formaldehyde) and ketones (e.g., methyl ethyl ketone, methyl isobutyl ketone).
- *Semi-volatile Organic Compounds (SVOCs)* – Compared to VOCs, these pollutants have a lower vapor pressure, are less reactive than carbonyls and include polynuclear aromatic hydrocarbons (PAHs) such as anthracene, benzo(a)pyrene and naphthalene.

Potentially, classifiable as a HAP, particulate matter can adversely affect lung function and play a role in the formation and dispersion of HAPs. Segregated by size: PM₁₀ (inhalable), PM_{2.5} (fine) and PM_{0.1} (ultrafine), the term particulate matter generally represents more common references to atmospheric fall-out, soot and dust.

PM may contain constituents from natural sources such as smoke particles from forest fires, salt particles from sea spray, windblown dust from unstabilized soil, or viable particles such as pollen and spores. From anthropogenic activities, PM can contain inorganic materials such as trace metals (e.g., arsenic, cadmium, lead); pure elemental material (e.g., elemental carbon); or complex mixtures of unburned and partially burned hydrocarbons (e.g., fine and ultrafine PM). PM may also form in the

atmosphere from chemical reactions involving precursor inorganic compounds, such as oxides of nitrogen or sulfur, and form inorganic particulate compounds (e.g., nitrates, sulfates).

Recently, ultrafine particles have been getting more publicity in the scientific community. Most ultrafine particles (on a count basis) are less than 0.1 micron in diameter. However, the research on ultrafine particles in aircraft exhaust is on-going, involves numerous international researchers, and is advancing what is known about this topic. The work is not yet complete, and the collected data are not fully analyzed. Instead of monitoring ultrafine particles, as part of the design of the Logan International Airport Air Quality Monitoring Study the monitoring of black carbon at the active monitoring sites was selected because it has been shown in other airport studies to be a good surrogate for aircraft exhaust impacts.

3.2.2 Evaluation Criteria

As with the monitoring site selection process, the identification and selection of pollutants to be included in the Study is central to its overall success. This process involves several key considerations, the most significant of which are briefly discussed below.

- *Representative of Airport-related Emissions* – It is important that the collected data be representative of pollutants that are associated with aircraft and airport activities. Notably, the EPA and FAA have identified the 13 compounds listed in **Table 3-2** that are classifiable as toxic and together represent over 96 percent of the total HAPs associated with airports.³ Adding fine PM (i.e., PM_{2.5}) to this list provides a comprehensive record of pollutants expected to occur near Logan, and taken together these pollutants serve as plausible candidate target pollutants for inclusion in the monitoring program.
- *Useful as Baseline Data for Future Studies* – Consideration is given to the usefulness and application of the collected data by other researchers in the future. These studies will likely focus on compounds that are common to airport activities and of potential interest from the standpoint of human health. For example, trace levels of benzene exist in the exhausts of aircraft, GSE and other airport sources and it is a known human carcinogen. In elevated concentrations, PM_{2.5} is reported to aggravate respiratory problems.
- *Comparison to Criteria and Other Monitoring Data* – As noted above, there are no NAAQS for the vast majority of compounds classifiable as air toxics or HAPs (except lead). However, EPA has published guideline values (called Reference Concentrations, RfCs) for acceptable inhalation exposure levels of some HAPs. Another potential basis for comparison is air monitoring data collected in other

³ *Select Resource Materials and Annotated Bibliography on the Topic of Hazardous Air Pollutants Associated With Aircraft, Airports and Aviation, prepared for the Federal Aviation Administration, July 2003.*

areas of Boston such as the MADEP Harrison Avenue and Lynn monitoring sites.⁴ These factors are considered and other attempts are made to select compounds to which the results of the Study can be meaningfully compared and evaluated.

Table 3-2 Airport-Related HAPs	
1,3-Butadiene (VOC)	Lead (Metal)
Acetaldehyde (Carbonyl)	Naphthalene (SVOC)
Acrolein (Carbonyl)	Propionaldehyde (Carbonyl)
Benzene (VOC)	Styrene (VOC)
Ethylbenzene (VOC)	Toluene (VOC)
Formaldehyde (Carbonyl)	Xylene (VOC)
PAHs: 2,2,4-Trimethylpentane, Acenaphthylene, Phenanthrene, Fluorene, Fluoranthene, Pyrene, Anthracene, Acenaphthene, Benzo(ghi)perylene, Benzo(bk)fluoranthene, Benzo(a)anthracene, Benzo(a)pyrene, Chrysene, Indeno(123-cd)pyrene, and Dibenzo(ah)anthracene (SVOCs)	

(Listed in alphabetical order.)

Source: FAA, 2003.

VOC – volatile organic compounds

SVOC – semivolatile organic compounds

PAH – polynuclear aromatic hydrocarbons

- *Substitute and Surrogate Compounds* - Because outdoor levels of HAPs occur in such very low concentrations, it can be difficult to obtain air samples that contain sufficient amounts of the compounds to measure. This is particularly true when sampling in “real-time” and over short time intervals (e.g., < 24 hours for some compounds and < 3 days for others). Therefore, consideration is also given to monitoring substances that are not classifiable as HAPs but may serve as indicators of their presence and relative abundance. For this Study, these surrogates include PM_{2.5}, black carbon and total VOCs.

The recommended Target Pollutants and the basis for their selections are discussed in Section 4.

3.3 Measurement Methods

Equally important to the selections of the monitoring sites and the Target Pollutants for the Study, is the evaluation and choice of monitoring methods.⁵ Ambient levels of HAPs typically occur in very low concentrations and many of them are easily volatilized or are otherwise reactive. These characteristics present a unique set of challenges that are not so important when monitoring other types of air pollutants.

⁴ Harrison Avenue site in Roxbury is approximately four miles SW of Logan and the Lynn site is approximately 7.5 miles north-northeast of Logan.

⁵ For the purposes of this Work Plan, the terms “monitoring” and “sampling” are used interchangeably.

Over the years, numerous methods have been developed to collect and analyze air pollutant samples, using both active and passive techniques. In general terms, active sampling techniques involve using mechanical means (e.g., a pump) to move air into, or through, a collection medium for analysis. Typical examples include high volume (hi-vol) samplers for PM and continuous monitors for CO or O₃. By comparison, passive sampling techniques involve using non-active means (e.g., diffusion, gravitational settling) to move air into or through a collection medium.⁶ Applied to this Study, the evaluation of candidate monitoring methods for HAPs involved the assessment of the following factors:

- *Reliability of Measurements* - Because the results of the Study will be used to evaluate low levels of air pollutants and be shared with MADEP/MADPH, the data must be as accurate and reliable as possible. Therefore, EPA-recommended or compiled methods are to be used wherever possible.
- *Applicability to Periodic and Follow-up Monitoring* - The MEPA Certificate calls for the “periodic air sampling” of HAPs – meaning monitoring on a seasonal, monthly, weekly or daily basis. Similarly, monitoring in advance of, and following, implementation of the Centerfield Taxiway is also required. These two directives involve the equipment set up, calibration and take-down between sampling periods or events. Therefore, the evaluation of monitoring methods takes into consideration the time and financial resources as well as the potential “wear and tear” on the equipment during this process.
- *Cost-effectiveness of Measurements* -In order to evaluate air quality conditions around the airport both spatially and temporally, a number of monitors or sampling devices must be run simultaneously at multiple locations. For this Study, meeting these requirements involves the careful balancing of available resources so that the types and quantity of data are appropriate and optimal while ensuring that the quality is not compromised.

Based upon these criteria, the recommended monitoring methods and the basis for their selections are discussed in Section 6.

3.4 Other Considerations

As discussed above and in keeping with the MEPA Certificate as well as the Primary and Supporting Objectives of the Study, the overall technical approach for the Work Plan is aimed at collecting the air quality data in locations around the airport using the most appropriate, reliable and cost-effective methods possible. Coupled with what has been learned from similar monitoring programs and responsive to the inherent difficulties in measuring low levels of air pollutants, this approach is also earmarked by several other important attributes, including:

⁶ Examples include diffusion badges and cartridges used in industrial hygiene or for the NO₂ Monitoring Program used at Logan since 1983 to monitor NO₂ levels in the surrounding communities.

- *Responsiveness to New Information and Changing Conditions* – During the initial stages of this Study, new information will be developed as the monitoring stations are deployed, the sampling methods are activated and the data is analyzed. This information will likely lead to adjustments in the Work Plan that improve data collection and identify other unforeseen opportunities or problems. These may include changes to site locations, sampling intervals and/or test parameters. Unexpected weather conditions or airport operational patterns may also justify modifications to the program in the longer term. For these reasons, the overall approach is designed to remain flexible throughout the course of the Study and responsive to these likelihoods.
- *Primary and Satellite Monitoring Sites* - It is not feasible to monitor HAPs in every neighborhood surrounding Logan. Moreover, air monitoring programs have shown that carefully selected sampling locations can provide representative information on the levels of air pollutants surrounding the airport. In this case, the establishment of “primary” (collocated full suite of active and passive monitoring) sites in select areas of particular interest coupled with “satellite” (primarily passive monitoring) sites enables the collection of representative data at multiple locations in the Study area. Massport developed this “hybrid” approach of using both active (real-time as well as time-integrated) measurements in the short term and passive (time-integrated) measurements in the long term. The differences between the active and passive air monitoring methods are distinguished and discussed in Section 6 (Monitoring Methods).

In the sections that follow, the individual components of the Work Plan are discussed in greater detail and enable the reviewer a more complete understanding of the approach including the recommended monitoring sites, the target pollutants and the monitoring methods and how their selections will help meet the objectives of the Study. Information pertaining to QA/QC procedures, and team roles and responsibilities are also provided.

Section 4

Target Pollutants

4.1 Introduction

As noted in both Sections 1 and 2, the MEPA Certificate states that the Study be conducted “with a special focus on air toxics.” Air toxics (also referred to as toxic air pollutants and HAPs, include a broad range of compounds for which there are no NAAQS, but are identified and regulated by EPA because of their potential effects on human health. Currently, 188 HAP categories (with over 700 subspecies) are regulated under the CAA. Emissions from multiple sources, including major stationary, area and mobile sources result in population exposure to these toxic air pollutants. EPA and state governments have established rules and emissions standards for many of these emissions sources to reduce ambient concentrations of these toxic air pollutants.

HAPs may be emitted from a variety of sources, both natural and anthropogenic. Of those that are man-made, many are emitted during combustion of petroleum-based fuels while others are emitted from industrial, chemical and waste treatment processes. Airport-related sources of HAPs were discussed previously in Section 2 and include aircraft, APUs and GSE; motor vehicles, maintenance equipment and construction activities; fuel facilities, boilers and an assortment of other minor sources, such as live-fire training activities and back-up generators.

The types of HAPs most commonly associated with airport-related sources are also identified in Section 2 and include the general categories of VOCs, carbonyls and SVOCs (including PAHs). One metal compound is also mentioned (e.g., lead).

The purpose of this section is to identify, evaluate and select the individual species of HAPs that are considered to be the most appropriate for this monitoring program. Therefore, they are called “Target Pollutants” in this Work Plan.

4.2 Selection Criteria

The basis for the identification, evaluation and selection of the Target Pollutants is centered largely on the following factors, or considerations:

- Classifiable as a HAP by EPA;
- Representative of airport-related emissions;
- Useful as baseline data for future studies;
- Comparable to regulatory criteria and monitoring data collected elsewhere by MADEP; and

- Identified in other studies as being useful in the assessment of potential airport air quality impacts.

The full listing of compounds classified as HAPs by EPA is too voluminous to be reprinted here so the reviewer is referred to these agency web sites on this topic.¹ The categories and individual species of HAPs most commonly associated with airports by the EPA and FAA are listed in Table 3-2 in Section 3.

4.3 Selected Pollutants

Following the approach and consideration discussed above, the Target Pollutants selected for this Study are listed in **Table 4-1**. For ease of reference, both the categories and names of the pollutants are shown along with indicators of their compatibility with the selection criteria.

Importantly, VOCs, carbonyls and SVOCs/PAHs are included among the group as they represent all the forms of combustion products or evaporative emissions from airport related sources.

Although not classified as HAPs by EPA, PM and BC also play a role in the formation and dispersion of HAPs. Moreover, aircraft-related emissions have been characterized by the presence of fine PM and BC. As surrogates to HAPs, they offer the double advantage of being quantifiable and potential indicators of airport air quality impacts. Therefore, they are also included as Target Pollutants for this Study.

¹ EPA, HAPs can be found at <http://www.epa.gov/ttn/atw/188polls.html>.

Table 4-1 Target Pollutants						
Category	Pollutant ¹	Classifiable HAPs ²	Airport-related ³	Baseline Useful ⁴	Criteria Comparable	Other Studies ⁵
VOCs	1,3-butadiene	x	X	x	x	x
	Benzene	x	X	x	x	x
	Carbon tetrachloride	x			x	
	Chloroform	x			x	
	Ethene	x			x	
	Ethylbenzene	x	X	x	x	x
	Styrene	x	X	x	x	x
	Toluene	x	X	x	x	x
	Vinyl chloride	x			x	
	Xylenes	x	X	x	x	x
Carbonyls	Acetaldehyde	x	X	x	x	x
	Acrolein	x	X	x	x	x
	Formaldehyde	x	X	x	x	x
	Propionaldehyde	x	X	x	x	x
Metals	Arsenic	x			x	
	Cadmium	x			x	
	Chromium	x			x	
	Lead	x			x	
	Manganese	x			x	
	Zinc	x			x	
SVOCs /PAHs	Naphthalene	x	X	x	x	x
	1-Methyl Naphthalene	x ⁶	X	x	x	x
	2-Methyl Naphthalene	x ⁶	X	x	x	x
PM	PM_{2.5}	See footnote 7	X	x	x	x
	Black carbon	See footnote 7	X	x	x	x

Footnotes

¹ Bolded compounds are recommended for potential inclusion as a Target Pollutant for this Study.

² Compounds classified as HAPs by EPA and DEP.

³ HAPs most commonly associated with airports by the EPA and FAA.

⁴ Based on how well the findings can ascertain the effects of the Centerfield Taxiway on air quality by comparison to pre-construction conditions and monitoring conducted elsewhere in the Boston area.

⁵ Identified as beneficial for assessing air quality conditions at other airports based upon other similar studies.

⁶ As constituents of Polycyclic Organic Matter (POM).

⁷ As a surrogate for products of combustion.

Abbreviations:

HAPs – hazardous air pollutants
PAH – polynuclear aromatic hydrocarbons
PM – particulate matter
SVOC – semi-volatile organic compounds
VOCs – volatile organic compounds

Section 5

Monitoring Locations

5.1 Introduction

The purpose of this section is to identify air monitoring sites that best meet the Primary and Supporting Objectives of the Study. The locations of the candidate sites are illustrated on **Figure 5-1**. As shown, there are 6 potential sites on the airport (Nos. 1 through 6) and 19 in the neighboring communities (designated A through S).

For ease of reference, **Figure 5-1** also contains annual, winter, and summer wind roses for Logan Airport and identifies locations in the vicinity of the airport that reportedly experienced odor complaints in the past. Soot and NO₂ monitoring locations presented in **Appendix C** and Logan flight path usage data presented in **Appendix D** were also considered.¹ Other factors that went in to the initial identification of the 26 sites were discussed previously in Section 3.

5.2 Site Selection Process

In order to obtain first-hand information on each site, field visits were conducted by Project Team members from Massport, CDM, KB Environmental Sciences, and Emory University. As a means of recording the information, a Site Evaluation Matrix was compiled using the criteria discussed in Section 3 and other supporting information. **Appendix A** contains the completed matrix as well as ground level photographs of each site looking north, east, south and west.

Using the evaluation criteria combined with the ranking guide discussed in Section 3, **Table 5-1** presents the outcome of the site evaluation process. A color-code system was used to rank each site (i.e., green = good, yellow = marginal, red = problematic). The results are discussed further in the next two subsections and sub-divided into Primary and Satellite Sites.

5.3 Primary Sites

In the site selection process emphasis was placed on meeting the Primary Objective of the Study - which is to collect ambient air quality data under (or near) the flight paths and in the neighborhoods surrounding Logan. Because the principle operational configuration of Logan is north-south and the airport is bordered to the east and south by Boston Harbor, the majority of these sites were located off the airport in East Boston and Winthrop with others located in South Boston. Several sites were ranked as “good” sites. These sites included:

¹ Vanasse Hangen Brustlin, Inc., *Logan International Airport 2004 Environmental Status and Planning Report (ESPR)* prepared for Massport, 2004.

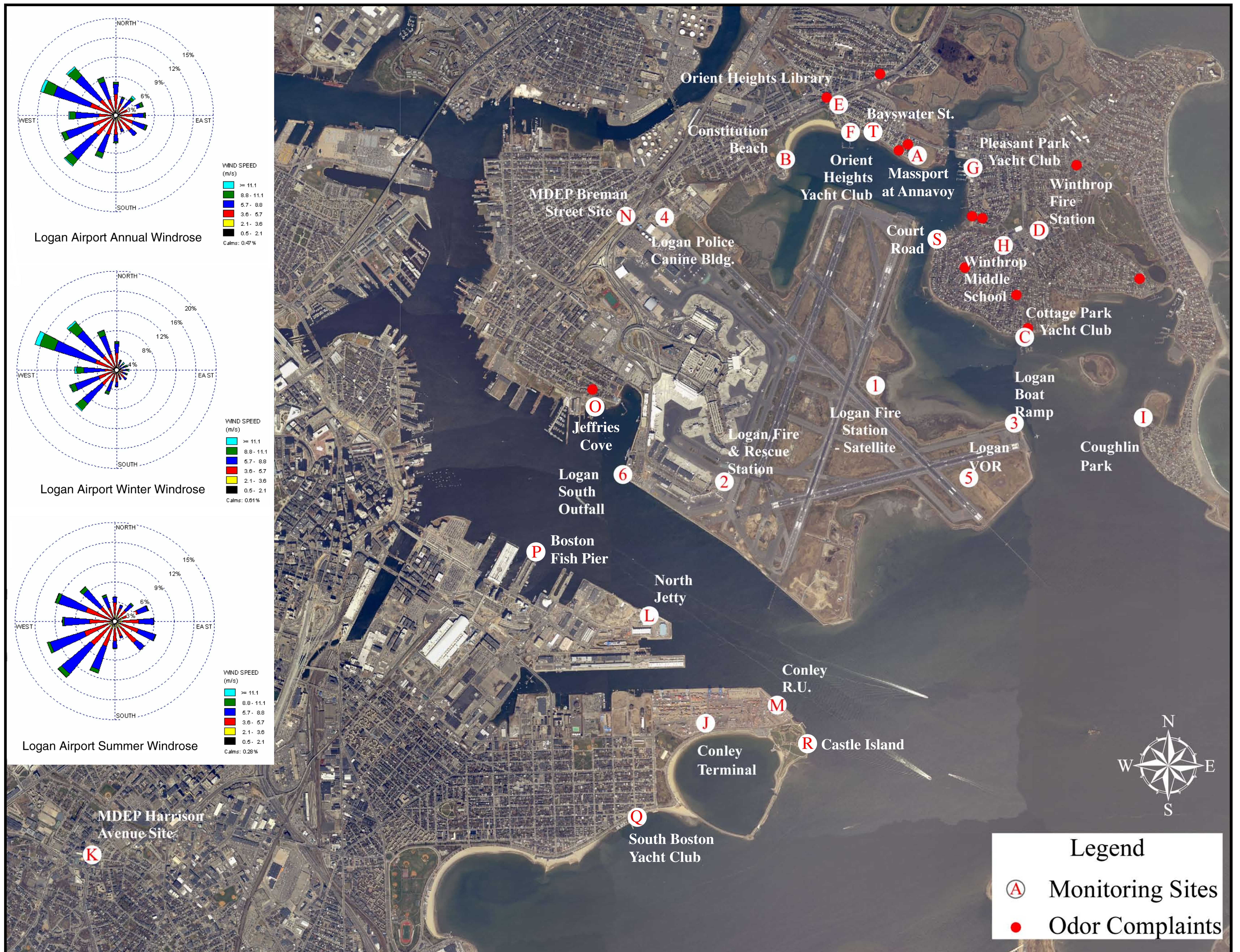


Table 5-1: Summary of Logan Airport Air Monitoring Site Evaluation

Site No./Designation	1	2	3	4	5	6	A	B
Site Name	Logan Satellite Fire Station	Logan Fire & Rescue Station	Logan Boat Ramp	Logan Police Canine Bldg.	Logan Runway VOR/Milk Bottle	Logan South Outfall/ Bird Island Flats	Massport @ Annavoy Street	Constitution Beach
MEPA Requirement								
Neighborhood	No	No	No	No	No	No	Yes	Yes
Residential	No	No	No	No	No	No	Yes	Yes
Under or Near Flight Path	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Distance/Direction to Centerfield Taxiway	<0.3 miles, E	0.3 miles, E	1 mile, E	1 mile, W	0.9 miles, mile E	0.8 miles W	0.4 miles, N	0.6 miles, NW
Nearby Emission Sources & Influence, except Airport	None	None	None	Near roadway, idling non- road equip. & Logan fuel farm	None	Aldehydes odors from deicing outfall	Surface traffic, residential heating units	Surface traffic, residential heating units
Upwind/Downwind	Downwind in Winter & Summer	Upwind in Winter & Summer	Downwind in Winter & Summer	Upwind in Winter & neutral in Summer	Downwind in Winter & Summer	Upwind Winter & Summer	Downwind in Summer & neutral in Winter	Upwind in Winter & neutral in Summer
Property Ownership	Massport	Massport	Massport	Massport	Massport	Massport	Massport	Municipal
Security/Vandalism	Secure Location	Secure Location	Secure Location	Secure Location	Secure Location	Secure Location	Partial fence, some vandalism risk	Low Security
FAA Involvement	May require FAA approval.	May require FAA approval.	Requires FAA approval.	May require FAA approval.	Requires FAA approval.	May require FAA approval.	Requires FAA approval.	No
Road Access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shelter/Existing Building	Existing Bldg.	Existing Bldg.	Shelter Required	Shelter Required	Existing Bldg.	Shelter Required	Shelter Required	Shelter or Bldg.
Electricity Availability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Site Availability (Short- / Long-term)	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.
Soot and NO ₂ Monitoring Site	No	Yes	No	No	No	Yes	Yes	Yes
Percentage of Time Under or Near Flight Path	<30%	<30%	>50%	<30%	>50%	<30%	30-50%	<30%
Other Notes				Idling heavy equipment could be a problem.	FAA building could be used.	Aldehydes from deicing chemicals.	2 nd utility pole owned by Massport. Met. station onsite.	Lt. Louis E. Porrazzo Rink
Overall Ranking	Marginal	Problematic	Problematic	Problematic	Marginal	Problematic	Good	Problematic

Legend

Good	Marginal	Problematic
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Table 5-1: Summary of Logan Airport Air Monitoring Site Evaluation cont.

Site No./Designation	C	D	E	F	G	H	I	J
Site Name	Cottage Park Yacht Club	Winthrop Fire Station	Orient Heights Library	Orient Heights Yacht Club	Pleasant Park Yacht Club	Winthrop Middle School	Coughlin Park	Conley Terminal
MEPA Requirements								
Neighborhood	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Residential	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Under or Near Flight Path	No	No	No	Yes	Yes	No	Yes	Yes
Distance/Direction to Centerfield Taxiway	0.9 miles, E	0.9 miles, E	0.6 miles, NW	0.4 miles, NNW	0.6 miles, NE	0.7 miles, E	1.7 miles E.	0.9 miles, S
Nearby Emission Sources & Influences, except Airport	Surface traffic, residential heating units	Busy surface road traffic	Busy surface road traffic	Surface traffic, residential heating units	Occasional Tugboat operations	Busy surface road traffic	Surface traffic, residential heating units	Ships & Diesel Equipment
Upwind/Downwind	Downwind Winter & Summer	Downwind in Summer & neutral in Winter	Downwind in Summer & neutral in Winter	Downwind in Summer & neutral in Winter	Downwind in Summer & neutral in Winter	Downwind in Summer & neutral in Winter	Downwind in Winter & Summer	Upwind Winter & Summer
Property Ownership	Cottage Park Yacht Club	Municipal	Municipal	Orient Heights Yacht Club	Pleasant Park Yacht Club	Municipal	Municipal/Private	Massport
Security/Vandalism	Secure security, poss. vandalism risk	Secure Location	Some security, poss. vandalism	Some security, poss. vandalism	Some security, poss. vandalism	Some security, poss. vandalism	Low Security	Secure Location
FAA Involvement	No	No	No	No	No	No	No	No
Road Access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shelter/Existing Building	Existing Bldg.	Existing Building	Existing Bldg.	Existing Bldg.	Existing Bldg.	Existing Bldg.	Shelter Required	Existing Bldg.
Electricity Availability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Site Availability (Short- / Long-term)	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.
Soot & NO ₂ Monitoring Site	Yes	No	No	Yes	Yes	No	Yes	No
Percentage of Time Under or Near Flight Path	<30%	<30%	<30%	30-50%	30-50%	<30%	>50%	>50%
Other Notes	Approval letter from Commodore	Tower with met station	Limited space around bldg	Flat roof bldg, approval letter from Commodore	Approval letter from Commodore		Noise monitor & Open Yard at 27 Grandview Road (Private Property)	Many local sources. Aircraft do not crossover site during takeoffs.
Overall Ranking	Marginal	Marginal	Problematic	Good	Good	Marginal	Good	Problematic

Legend

Good	Marginal	Problematic
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Table 5-1: Summary of Logan Airport Air Monitoring Site Evaluation cont.

Site No./Designation	K	L	M	N	O	P	Q	R	S	T
Site Name	MDEP Harrison Avenue Site	North Jetty Site	Conley Refrigeration Units	MDEP Breman Street Site	Jefferies Cove	Massport – Boston Fish Pier	South Boston Yacht Club	Castle Island	Court Road	Bayswater Street
MEPA Requirements										
Neighborhood	No	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes
Residential	No	No	No	Yes	Yes	No	Yes	No	Yes	Yes
Under or Near Flight Path	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Distance/Direction to Centerfield Taxiway	4 miles, SW	0.7 miles, SW	0.8 miles S.	1.2 miles, W	1.2 miles, W	1.4 miles, SW	1.9 miles, SSW	1.1 miles, SSE	0.3 miles, E	0.4 miles, N
Nearby Emission Sources & Influences, except Airport	Very busy surface road traffic	Port activities.	Ships and Diesel Equipment.	Route 1A traffic, commercial & light industrial sources	Surface road traffic	Ships and Diesel Equipment Idling	Busy surface road traffic	Conley Terminal – Idling Diesel Truck Engines	Surface road traffic, residential heating units.	Surface traffic, residential heating units
Upwind/Downwind	Upwind Winter & Summer	Upwind in Winter & Summer	Upwind in Winter & Summer	Upwind in Winter & neutral in Summer	Upwind in Summer & Neutral Winter	Upwind in Summer & Neutral Winter	Upwind in Summer & Neutral Winter	Neutral Summer & Winter	Downwind in winter and summer.	Downwind in Summer & neutral in Winter
Property Ownership	Boston Edison	Massport	Massport	NStar	East Boston	Massport	South Boston Yacht Club	City of Boston	Private Owner	Private Property
Security/Vandalism	Secure Location	Secure Location	Secure Location	Secure Location	Low Security	Secure Location	Some security, poss. vandalism	Low Security	Some security, poss. vandalism	Partial fence, some vandalism risk
FAA Involvement	No	No	No	No	No	No	No	No	No	No
Road Access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shelter/Existing Building	Existing Shelter	Shelter Required	Existing Bldg.	Shelter in place	Shelter Required	Existing Bldg.	Shelter/Existing Bldg. Poss.	Castle Island Fort poss.	Shelter/Existing Bldg. Poss.	Shelter Required
Electricity Availability	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Site Availability (Short- / Long-term)	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.
Soot & NO ₂ Monitoring Site	No	No	No	Yes	Yes	No	No	No	Yes, nearby Loring Road NO ₂ monitor	No
Percentage of Time Under or Near Flight Path	<30%	>50%	>50%	<30%	<30%	>50%	>50%	>50%	30-50%	30-50%
Other Notes	Good site to represent urban background.	Long-term warehouse const. Site away from neighborhood				Abandoned weigh scale buildings for shelters	Massport noise monitoring location, approval letter from Commodore	Located next to Conley Terminal, potential passive monitoring site only		
Overall Ranking	Problematic	Problematic	Problematic	Good	Marginal	Marginal	Marginal	Problematic	Good	Good

Legend

Good

Marginal

Problematic

- Massport at Annavoy Street, East Boston;
- Orient Heights Yacht Club, East Boston;
- Pleasant Park Yacht Club, East Boston;
- Coughlin Park, Winthrop; and
- Court Road, Winthrop.

MADEP and MADPH comments and feedback on the Draft Work Plan were also taken into consideration in the final selection of the Primary Sites.

Brief descriptions of the three selected Primary Sites are presented below.

- **Massport at Annavoy Street:** This site is located in East Boston adjacent to the Winthrop town line directly across a harbor inlet from the proposed Centerfield Taxiway, approximately 0.4 mile north of the airport. This site was ranked overall as “good” because it meets the Primary Objective of being located in a residential neighborhood and under the flight path. This site also has the advantage of being predominantly downwind from the airport during the summertime and periodically so during the remainder of the year. The site is owned by Massport and partially occupied by an FAA navigation system. In addition, the site has power available and it has both short- and long-term availability. It is also currently in the Massport NO₂ monitoring program and is in an area that has experienced odor complaints in the past. Disadvantages are that the site is only partially secure on three sides, FAA approval is required and there is no existing building that can be used to house the air monitoring equipment. Other nearby emission sources include motor vehicle traffic operating on the local roadway network and the burning of fuel in home heating units.
- **Court Road** This site is located in Winthrop approximately 0.3 mile east of the proposed Centerfield Taxiway. This site was ranked “good” overall because it meets the Primary Objective of being located in a residential neighborhood and near the flight path. This site is downwind from Logan during both the winter and summertime. The site has good road access, electric power is available, and it does have an existing building (the residence or garage) that may be available to house the air monitoring equipment. Likewise, the site has short- and long-term availability and is near one of the Massport NO₂ sampling sites. The disadvantages of this site are that it is only partially secure, is privately-owned and will require approval and ongoing cooperation from the home-owner.
- **MDEP Bremen Street Site:** This site is located in E. Boston approximately 1.2 miles to the west of the proposed Centerfield Taxiway. This site was ranked “good” overall because it meets the Primary Objective of being located in a residential neighborhood and under the flight path. This site is upwind from the airport during the winter and mostly remains so during the remainder of the year.

The site has good road access, electric power is available, and it does have an existing shelter that may be used to house the monitoring equipment. In addition, the site has short- and long-term availability and it is one of the Massport NO₂ sampling sites. The disadvantages are that the site is privately-owned, and will require approval and ongoing cooperation from the owner. Nearby sources of emissions include the traffic on Route 1A and the nearby commercial/light-industrial areas.

5.4 Satellite Sites

As discussed above, the purpose of the Satellite Sites is to expand the Study Area into neighborhoods surrounding the airport that are spatially distant from the Primary Sites. It is anticipated that up to seven Satellite neighborhood monitoring locations and one urban background monitoring location (Harrison Avenue) will be used in the Study, including:

- Coughlin Park, Winthrop;
- Cottage Park Yacht Club, Winthrop;
- Harrison Avenue, Roxbury;
- Jeffries Cove, East Boston;
- Constitution Beach, East Boston;
- Bayswater Street, East Boston;
- South Boston Yacht Club, South Boston; and
- Logan Fire Station – Satellite Facility, East Boston (on airport).

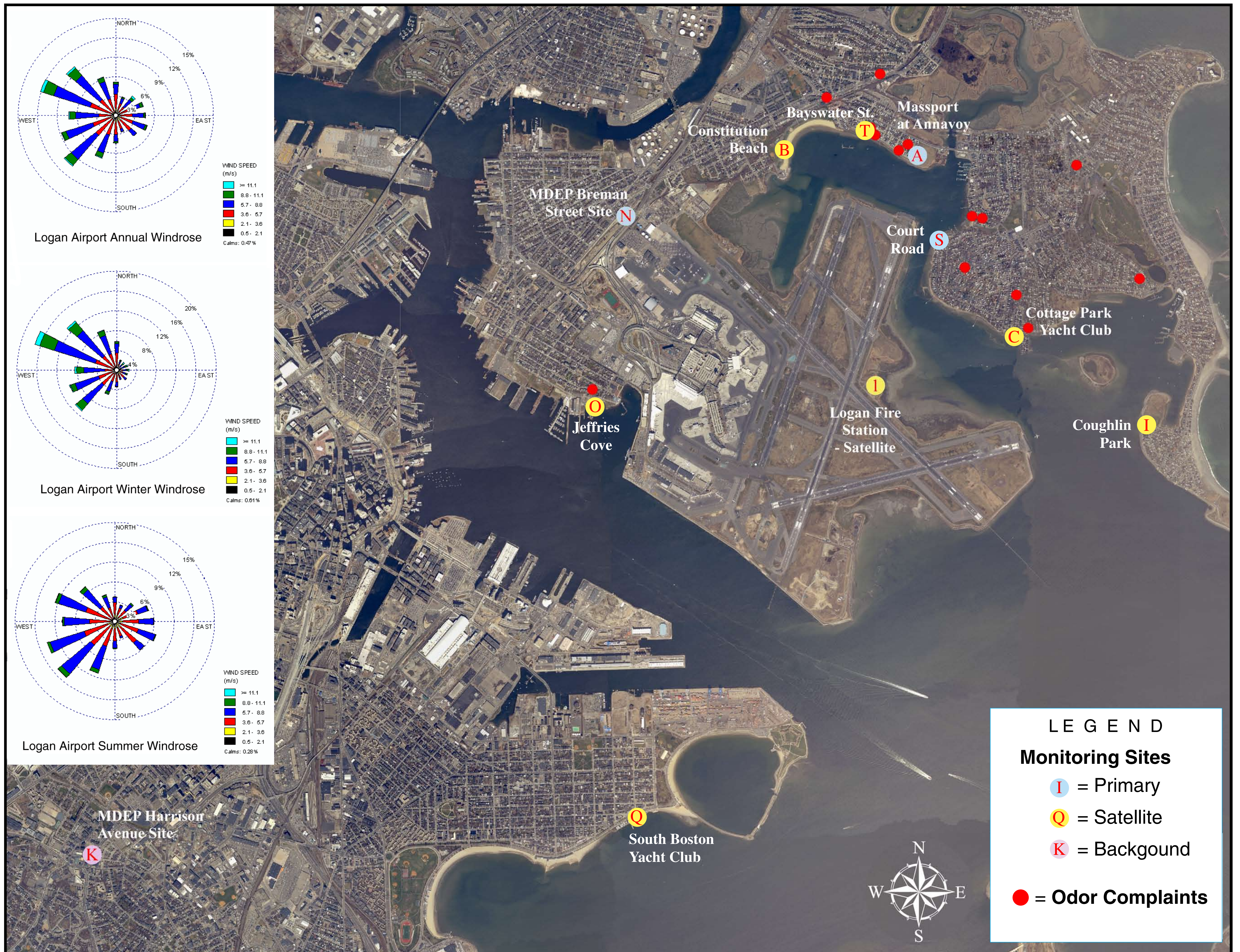
Because the passive monitoring equipment is more portable than the active monitoring equipment, other off-airport monitoring locations may also be monitored, if preliminary results of the Study deem it necessary.

Another off-airport air monitoring site that is also considered a valuable site is the MADEP Harrison Avenue site. The MADEP operates and maintains a monitoring station that measures the toxic air pollutants, PM_{2.5} and black carbon. Therefore, this site could serve as a background site representing urban air quality conditions.

It is recommended that three primary and seven satellite monitoring locations will be used for this Study. Passive monitors are also recommended at the MADEP Harrison Avenue site as a background site. **Table 5-2** and **Figure 5-2** present the monitoring locations for the Study.

Table 5-2 Air Monitoring Locations		
Candidate Sites	Site Designation	Monitoring Station Type
Annavoy Street, East Boston	A	Primary
MADEP Bremen Street, East Boston	N	Primary
Court Road, Winthrop	S	Primary
Coughlin Park, Winthrop	I	Satellite
Jeffries Cove, East Boston	O	Satellite
South Boston Yacht Club, South Boston	Q	Satellite
Bayswater Street, East Boston	T	Satellite
Cottage Park Yacht Club, Winthrop	C	Satellite
Constitution Beach, East Boston	B	Satellite
Logan Satellite Fire Station, East Boston	1	Satellite
MADEP Harrison Avenue Site, Roxbury	K	Background

Note: Primary stations include both active and passive monitoring and satellite stations include primarily passive monitoring. Passive monitors will also be set up at the MADEP Harrison Avenue site.



Section 6

Monitoring Methods

Section 4 identified the Target Pollutants selected for the Study. This section describes the monitoring methods which are based on these pollutants of interest.

Massport developed specifically for this application at Logan International Airport a “hybrid” approach of using both active (real-time as well as integrated) measurements in the short term and passive (integrated) measurements in the long term. Both monitoring approaches vastly expand the monitoring network and enable the most comprehensive assessment of ambient conditions possible. A more traditional program of only using active methods would limit the data collection capabilities to one or two neighborhoods.

One difference between the active and passive air monitoring methods is the time periods (i.e., sampling durations) over which the samples are collected. For example, the active methods monitor air quality both in “real time” and as “integrated” samples over short time intervals (i.e., 1 minute to 24 hours). Combined with concurrent meteorological and airport operational data, these active measurements may help identify and characterize the potential impacts from airport activities or events.

By comparison, the passive methods are used to monitor air quality only as “integrated” samples over longer time periods (i.e., several days or more) and bracketing the sample durations for the active integrated samples. When the results from several passive sampling sites are reviewed together, these data are intended to reveal neighborhood-scale trends or patterns in air quality conditions based on geographic location (i.e., direction and distance from the airport).

Table 6-1 summarizes the air monitoring methods planned for use in the Study. These monitoring methods are discussed further below.

6.1 Active Methods

Active sampling typically involves using mechanical means (e.g., a pump) to move air into (or through) a collection medium (e.g., activated charcoal, chemically treated sieves, vacuum cylinders). The collected samples are then extracted for analysis in a laboratory using assorted chemical and physical methods. A variation on the collection and analytical steps involves continuous monitoring instruments that collect and analyze the air sample *in-situ* (or in the monitoring device).

6.1.1 Time-Integrated Sampling Devices

The time-integrated techniques are described below, by pollutant:

- **VOCs** - An active VOC sampler consists of an evacuated stainless steel canister having the interior surface polished, cleaned, and passivated using the Summa®

process. A metal bellows-type pump is used to draw outside ambient air into the canister, pressurizing it to slightly above atmospheric pressure. Outside ambient air is drawn into the canister through a Teflon sampling line and particulate filter with the flow rate controlled by a calibrated volumetric flowmeter. The flowmeter also controls the duration of sampling. Ambient samples are typically collected in a 6-liter canister, but canisters of different volumes (e.g., 1 liter, 15 liter) may also be used. This method is consistent with EPA Method TO-15 (*Determination of VOCs in Air Collected in Specially-Prepared Canisters and Analyzed By GS/MS*).

Table 6-1 Air Monitoring Methods		
Pollutant and Method	Technique	Averaging Time
Meteorology (wind speed and direction, temperature and humidity)	Active	Continuous
PM _{2.5} mass using beta attenuation monitor (BAM) with very sharp cut cyclone	Active	Real time
Black carbon using seven-wavelength aethalometer	Active	Real time
Volatile organic compounds (VOC) using Summa canister with GC/MS ¹ analysis ²	Active	Integrated
PM _{2.5} Federal Reference Method (FRM)	Active	Integrated
PM _{2.5} (Minivol)	Active	Integrated
Carbonyl compounds using DNPH ³ adsorber with HPLC ⁴ analysis ⁵	Active	Integrated
Polynuclear aromatic hydrocarbons (PAH) using sequential sampler with Teflon-coated glass-fiber filter and XAD ⁶ cartridge with GC/MS analysis ⁷	Active	Integrated
Volatile organic compounds (VOC) using passive adsorber with GC/FID ⁸ analysis ⁹	Passive	Integrated
Carbonyl compounds using DNSH ¹⁰ passive adsorber and HPLC with fluorescence analysis ⁵	Passive	Integrated
Polynuclear aromatic hydrocarbons (PAH) using diffusive passive sampler with GC/FID analysis ⁷	Passive	Integrated

¹GC/MS = gas chromatography/mass spectrometry.

²Target VOCs include benzene, toluene, ethylbenzene, xylenes, styrene, and 1,3-butadiene.

³DNPH = diphenylhydrazine.

⁴HPLC = high performance liquid chromatography.

⁵Target carbonyl compounds include acetaldehyde, acrolein, formaldehyde, and propionaldehyde.

⁶XAD[®] = a proprietary resin XAD sorbent.

⁷Target PAHs include naphthalene, 1-methyl naphthalene, and 2-methyl naphthalene.

⁸GC/FID = gas chromatography/flame ionization detector.

⁹The passive VOC sampler will not be able to resolve 1, 3-butadiene.

¹⁰DNSH = dansyl hydrazine.

- **Carbonyls** - An active carbonyl sampler consists of a prepackaged cartridge containing acidified 2,4-dinitrophenylhydrazine (DNPH). A sampling pump provides the mechanical means to induce air flow into the cartridge. Outside ambient air is drawn through the cartridge using a Teflon sampling line having the sample rate controlled by a calibrated pump. The pump also controls the duration of sampling. The flow rate is established to sample a known volume of air for an appropriate integration period. This method is consistent with EPA Method TO-11A (*Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by HPLC*).
- **SVOCs/PAHs** - An active PAH sampler consists of a low-volume air sampler utilizing a filter and sorbent cartridge containing XAD-2 sorbent. Outside air is drawn into a sampling train with the sampling rate controlled by a calibrated blower fan, bringing the air sample through the filter then through the sorbent cartridge. The blower fan also controls the duration of sampling. The flow rate is established to sample a known volume of air for an appropriate integration period. This method is consistent with EPA Method TO-13A (*Determination of Polycyclic Aromatic Hydrocarbons in Ambient Air Using GC/MS*).
- **PM_{2.5}** - An active PM_{2.5} sampler consists of a low-volume air sampler utilizing a filter substrate to collect fine particulate matter. Outside air is drawn through a precision cut-point inlet head by a calibrated blower fan, bringing the air sample through the filter. The blower fan also controls the duration of sampling. The flow rate is established to sample a known volume of air for an appropriate integration period. At one of the Primary sites (Annavoy Street), PM_{2.5} will be collected using an EPA federal reference (or equivalent) method (40 CFR 50 Appendix L – *Reference Method For the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere*). At all Primary sites and all Satellite sites, PM_{2.5} will also be collected using a technique not currently recognized as a federal reference (or equivalent) method (Airmetrics MiniVol™ Portable Air Sampler).

A sampling period of 24 consecutive hours (midnight to midnight) is planned for these time-integrated sampling methods to obtain adequate sample for analysis with low levels of detection. An air inlet, manifold system and blower will supply outside air to the samplers (except the PM_{2.5} samplers which have their own inlets), drawing air from a height above the ground representing the breathing zone of an adult human. Each sample will be documented with a unique sample number, and sample handling will be controlled following strict “chain-of-custody” procedures.

6.1.2 Real-Time Continuous Monitoring Devices

The real-time techniques are described below, by pollutant:

- **PM_{2.5}** - Ambient concentrations of PM_{2.5} will be monitored in real time using a beta attenuation monitor (BAM) with a very sharp cut cyclone PM_{2.5} sampling inlet. The BAM uses a continuous glass fiber filter tape to measure nearly continuous concentrations of PM_{2.5}. The instrument uses a small ¹⁴C source of beta

particles coupled with a sensitive detector to count the beta particles. The detector measures the transmission of beta particles through a clean section of the tape. The tape is then mechanically advanced and ambient air is drawn into the instrument sampling inlet and particulate matter is deposited on the tape. At completion of the sampling period, the tape is returned to the original location and the beta particle transmission is re-measured. The difference between the two measurements is proportional to the PM_{2.5} concentration; as the mass of particulate matter deposited on the tape increases, the measured beta particle count is reduced according to a known equation. While this monitoring instrument has not yet been designated by EPA as a reference or equivalent method for purposes of PM_{2.5} compliance monitoring, research studies have found it to produce reliable measurements.

- **Black Carbon** - Ambient concentrations of black carbon will be monitored continuously using a seven-wavelength aethalometer. The aethalometer collects particulate matter continuously on a quartz fiber filter tape and determines the increment of optically absorbing material collected per unit volume of sampled air. Since elemental (or black) carbon is the dominant optically absorbing material in the submicron size range, this measurement is interpreted as a mass of black carbon according to calibrations performed by intercomparisons with chemical analysis techniques. The optical measurement is ratiometric and no external calibration materials are required.
- Both the BAM and the aethalometer require a 110-volt, 60-Hz power supply in a stable, temperature-controlled environment, since the instruments contain sensitive electronics. Again, an air inlet, manifold system and blower will supply outside air for the monitors, drawing from a height above the ground representing the breathing zone of an adult human being.
- **Meteorological Parameters** – Wind speed and direction and temperature and humidity measurements will be made at each active monitoring station. Instruments will be mounted on a mast and installed on top of two of the active monitoring stations (Annavoy Street and Court Road stations). Data will be collected in a data logger and downloaded to laptop weekly. Data will be retrieved from NStar’s meteorological station at the MADEP Bremen Street active monitoring station and data will also be retrieved from the National Weather Service meteorological station at Logan Airport to compare to data collected at each active monitoring site.

6.2 Passive Methods

Passive sampling involves using non-active means (e.g., molecular diffusion, gravitational settling, wind currents) to move air into or through a collection medium. The collected samples are then extracted for analysis in a laboratory using assorted chemical and physical methods. Passive monitoring methods will be used for VOCs, carbonyls and SVOCs/PAHs. While these monitoring methods are not EPA “reference” sampling methods, they have been used in numerous field studies and

have been found to provide reliable results. **Appendix E** provides support and reference materials supporting the passive monitoring methods presented below.

- **VOCs** - A passive VOC sampler consists of a small quantity of adsorbent medium housed in a collector having small pores to allow air to diffuse into the adsorbent. The adsorbent medium typically consists of charcoal or some proprietary sorbent. The sampler is small, approximately 7 centimeters (cm) in diameter and 2 cm thick.

Carbonyls - A passive carbonyl sampler consists of a small quantity of adsorbent medium housed in a collector having an opening to allow air to diffuse into the adsorbent. These samplers adsorb carbonyl compounds using the hydrazine-hydrazone reaction commonly used for aldehyde sample collection. An alternative sorbent to dinitrophenylhydrazine, dansyl hydrazine (DNSH), offers a significant improvement in sensitivity. The sampler is small and unobtrusive with a barrel length of about 7 cm and a diameter of about 0.5 cm.

SVOCs/PAHs - A passive PAH sampler consists of a small quantity of adsorbent medium housed in a collector having openings to allow air to diffuse into the adsorbent. This method uses standard gas chromatographic (GC) column material bound together as an adsorption medium. Approximately 320 1-cm sections of column are bound together in a holder for the collection of PAHs from air. The PAHs diffuse passively into the unobtrusive sampler, which is about 7 cm long, 2 cm wide and 1 cm thick.

For these passive samplers, exposure periods of seven consecutive days or longer will be used to obtain adequate sample mass for analysis with a low level of detection. Thus, they are classified as time-integrated samplers.

Each passive sampler will be mounted in a secure location at each primary and satellite monitoring station at a height above the ground representing the breathing zone of an adult human. Each passive sampler will be protected from the elements by partially enclosing it with a shield to protect it from precipitation, wind, and direct sunlight. Each passive sample will be documented with a unique sample number, and sample handling will be controlled following strict chain-of-custody procedures.

6.3 Monitoring Schedule

The real-time measurements of PM_{2.5} and black carbon will occur continuously throughout the two 12-month monitoring periods. The monitoring program for the other compounds will follow a pre-determined, or set sampling schedule (independent of other factors or activities). The set sampling schedule would provide an unbiased and standardized sampling approach over a consecutive 12-month period. Following such a schedule would provide representative annual average concentrations for pollutants being sampled on a non-continuous basis. The effects of meteorology as well as short-term and longer-term spatial and temporal variations in emission source patterns would be evaluated after the data are collected.

Table 6-2 summarizes the 12-month monitoring schedule. The dates for active sample collection will coincide with dates from the national EPA ambient network schedule, although not all such dates will see sampling activity. Because the extended exposure periods required for the passive sampling activities are not amenable to short-term fluctuations in meteorological and aircraft operational patterns, the passive sampling will follow a pre-determined seven day schedule. The passive samplers may be deployed for a longer sampling period to increase sensitivity based on a review of the first two months' worth of sampling data. If necessary, it is anticipated that the passive monitors could be deployed for up to one month in order to increase the sensitivity of the samplers.

Figure 6-1 presents an example routine sampling schedule for the planned first three months of network activity to portray the relationships and overlaps between the different parameters.

Massport, in consultation with MADEP and MADPH agreed that based on the review of the first 12-months of monitoring results, meteorological data and Logan Airport flight operations data that it may be appropriate to conduct a set of short-term sampling periods in addition to conducting a set sampling schedule during the second year of the monitoring program. The random sampling schedule would be conducted over the second consecutive 12-month period. Following such a schedule, which would be driven by empirical and changing conditions related primarily to the activity patterns of emission sources at the Airport, would attempt to capture short-term peaks of pollutant concentrations when they are expected to occur.

Table 6-2 Summary of Monitoring and Sampling Frequency					
Parameter	Type	Frequency	Duration	Averaging Time	Start Time
Meteorology	Active real time	Continuous	Continuous	15 minute	NA
PM _{2.5} (BAM)	Active real time	Near continuous	Continuous	1 hour	NA
Black carbon (aethalometer)	Active real time	Continuous	Continuous	5 minutes	NA
PM _{2.5} (FRM)	Active integrated	Every 6th day	24 hours	24 hours	12 Midnight
PM _{2.5} (Minivol)	Active integrated	Every 12th day	24 hours	24 hours	12 Midnight
VOC	Active integrated	Every 12th day	24 hours	24 hours	12 Midnight
Carbonyls	Active integrated	Every 12th day	24 hours	24 hours	12 Midnight
PAH	Active integrated	Once per month	24 hours	24 hours	12 Midnight
VOC	Passive integrated	Once per month	7 consecutive days	7 days	Variable
Carbonyls	Passive integrated	Once per month	7 consecutive days	7 days	Variable
PAH	Passive integrated	Once per month	7 consecutive days	7 days	Variable

Figure 6-1
Example Routine Sampling Schedule - Third Quarter 2007

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Section 7

Laboratory Methods

Samples collected using both the passive and active field methods discussed in Section 6 will be preserved, stored, and transported to appropriate laboratories for subsequent analyses. In accordance with the QAPP, all samples will be transferred between the field and laboratory following “chain-of-custody” procedures. Applicable holding and preservation times will also be observed for all samples.

Passive samples collected on diffusion badges or tubes, will be analyzed at Emory University, Atlanta, Georgia. Instrument measurements will be analyzed by CDM at their offices in Cambridge and active samples collected for chemical or gravimetric analyses will be sent to the Desert Research Institute, Reno, Nevada.

7.1 Passive Samples

At the laboratory, the analysis of the passive VOC samples will be accomplished through solvent extraction of the charcoal bed using carbon disulfide or similar solvent. After extraction, the extract will be injected directly into the gas chromatograph (GC) injection port with no further work up. Quantification will be accomplished with a flame ionization detector (FID).

Analysis of the passive carbonyl samples will be accomplished through solvent extraction of the derivatized carbonyl compound from the sorbent using acetonitrile. Quantification will involve gradient high performance liquid chromatography (HPLC) and fluorescence detection.

Analysis of the passive PAH samples will be accomplished through solvent extraction and GC analysis with a FID, similar to that described above for the passive VOC samples.

7.2 Active Samples

Analysis of the active VOC samples will be performed to be consistent with EPA Method TO-15 (*Determination of VOCs in Air Collected in Specially-Prepared Canisters and Analyzed By GS/MS*). A known volume of sample is directed through a solid multisorbent concentrator. After the concentrating and drying steps, VOCs are thermally desorbed and carried to a gas chromatograph for separation followed by mass spectrometry for analysis.

Analysis of the active carbonyl samples will be performed to be consistent with EPA Method TO-11A (*Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by HPLC*). The DNPH derivative is determined using isocratic reverse phase HPLC with an ultraviolet absorption detector. The HPLC system is operated in the linear gradient program mode.

Analysis of the active PAH samples will be performed to be consistent with EPA Method 13-A (*Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)*). The exposed filters and sorbent media are extracted by Soxhlet extraction with appropriate solvent. The extract is concentrated by a Kuderna-Danish evaporator, followed by silica gel clean up using column chromatography to remove potential interferences prior to analysis by gas chromatography/mass spectrometry.

Analysis of the time-integrated PM_{2.5} samples will be performed using gravimetric analysis either consistent with or similar to the EPA federal reference method (40 CFR 50 Appendix L—*Reference Method For the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere*). Following conditioning for a 24-hour period in a temperature and humidity controlled environment, an analytical balance is used to weigh both clean and exposed filters to the nearest 1 microgram. The weight difference between the exposed and clean filter is divided by the volume of air sampled to determine the concentration of PM_{2.5} in the sample.

Section 8

Quality Assurance Project Plan

As an important element of the Study, measures will be developed and implemented to help ensure that the monitoring methods and collected data are as reliable as possible. Using EPA guidance as a model, this initiative is referred to as the Quality Assurance Project Plan (QAPP) and will serve several purposes (EPA 1998).

According to the EPA guidance, projects involving environmental data collection should be conducted in three phases: a) Planning, b) Implementation, and c) Assessment. In the Planning phase, project objectives are clarified so that the requirements for the end user of the data are met. In the Implementation phase, the QAPP translates these data requirements into measurement performance specifications and quality assurance (QA) and quality control (QC) procedures. In the Assessment phase, the collected data are evaluated using statistical tools to evaluate whether the project objectives were met and whether the data are suitable for scientific interpretation and (if applicable) policy-making.

This Work Plan represents the first phase (Planning) of the QAPP by stating the primary and supporting objectives of the Study, including the purpose of the program and the intended use of the data. The second phase (Implementation) and third phase (Assessment) will be preceded by a written QAPP that will contain the QA/QC procedures for field and laboratory personnel and data management efforts. This information will be contained in a “stand-alone” document, separate from this Work Plan and made available to MADEP and MADPH for technical review and the general public.

Section 9

Data Analysis and Reporting

9.1 Introduction

This section describes the types of data that will be collected during the course of the Study and how it is expected to be analyzed and reported. The overall approach to this process is based upon several factors including:

- the selected target pollutants (see Section 4);
- the monitoring methods, timeframes and frequencies (see Section 6); and
- the expected use of the collected data by Massport, MADEP, MADPH and others.

Importantly, this approach does not preclude additional or alternative analyses in response to changes in the amounts of and types of data collected, any emergent trends and other notable findings and/or other potential uses of the data that are presently unanticipated.

9.2 Measurement and Reporting Units of Target Pollutants

Table 9-1 contains a summary listing the target pollutants (and other parameters) identified for inclusion into the Study. As shown, the pollutants comprise components of particulate matter (i.e., PM_{2.5} and black carbon) as well as an assortment of gaseous compounds (i.e., VOCs, PAHs and carbonyls).

Because particulate matter measurements are based on the mass (or weight) of the substance in the collected volume of air (i.e., mass/volume), these pollutants will be reported in units of micrograms/cubic meter (µg/m³). By comparison, gases are measured based on the amount of pollutant relative to the amount of collected air (i.e., volume/volume) and will be reported in units of parts per billion by volume (ppbv). These two sets of concentration units represent the common industry-accepted conventions for these types of pollutants.

9.3 Measurement Timeframes and Frequencies

Table 9-1 also shows the measurement (or sampling) averaging time periods and frequencies for the target pollutants and monitoring methods. As shown, the sampling times will range from 1 to 5 minutes (i.e., for particulates), daily (i.e., 24 hours for gaseous compounds) for active methods and extend to seven days (or longer) for passive methods involving gases. Similarly, the sampling frequencies range from continuous (for particulates) to once every 12 days (for gases using active methods) to once a month (for gases using passive methods).

Table 9-1 Summary of Study Parameters, Reporting Units and Statistics			
Parameter	Reporting Units	Averaging Time Period	Summary Statistics
PM _{2.5}	µg/m ³	1 hour 24-hour	Maximum, minimum and means by site - overall, by day of the week, month and 12-month period. (As above)
Black carbon	µg/m ³	5-minute	(As above)
VOCs	ppbv	24-hour (active) 7-day (passive)	(As above; by compound.)
Carbonyls	ppbv	24-hour (active) 7-day (passive)	(As above; by compound.)
PAHs	ppbv	24-hour (active) 7-day (passive)	(As above; by compound.)
Meteorology			
Wind Direction	degrees	1 hour	12-month period, monthly, daily and hourly
Wind Speed	mph	1 hour	(As above)
Temp.	°F	1 hour	(As above)
Rel. Humidity	%	1 hour	(As above)
Airport Operations	Landings & take offs	1 hour	12-month period, monthly, daily and hourly.
Traffic	Vehicles	1 hour or 24 hour	12-month period, monthly, daily and hourly

Notes:

°F = degrees Fahrenheit; µg/m³ = micrograms per cubic meter; mph= miles per hour; PAHs = polynuclear hydrocarbons; PM_{2.5} = particulate matter with an equivalent aerodynamic diameter equal to or less than 2.5 microns; ppbv = parts per billion by volume; VOCs = volatile organic compounds; W = wind.

This wide variation in sampling timeframes and frequencies reveals that the amounts of collected data will also vary according to the pollutant types (particulates vs. gases) and measurement methods (active real time, active time integrated, passive time integrated). For example, over a 12-month sampling period, real time monitoring (5-minute sampling) will yield approximately 100,000 measurements; active time-integrated will yield 30 to 60 measurements; and passive time-integrated will yield 12 measurements at each monitoring site.

9.4 Meteorological and Other Supporting Parameters

The monitoring and reporting of meteorological conditions, airport operations and motor vehicle traffic will also be conducted as part of the Study. It is expected that the

assessment of these parameters will aid in the understanding of the measured pollutant levels and their trends.

As discussed in Section 6, wind speed and direction, temperature and humidity measurements will be made at each primary monitoring station. The reporting units are based on degrees of compass direction (°), miles per hour (mph), degrees Fahrenheit (°F), and percent (%), respectively. The data from the Annavoy Street and Court Road stations will be collected in an electronic data logger and downloaded weekly to a laptop computer. Data will also be retrieved from NStar's meteorological station adjacent to the MADEP monitoring station and the National Weather Service meteorological station at Logan Airport.

Airport operational data will be obtained by Massport for the entire Study period, will consist of aircraft landings and takeoffs at Logan and will be segregated by runway end (e.g., 22R) and time of day (e.g., 0900 – 1000).

Surface traffic (e.g., motor vehicle) data for the Study Area roadway system will be obtained from the Massachusetts Highway Department (MHD), Massport and other state or local agencies (to the extent it is available) and reported as vehicles per day (veh./day) or vehicles per hour (veh./hr.). Notably, these data are used to establish general conditions and trends and not to monitor individual roadways.

9.5 Data Analysis and Presentation

As presented in Sections 5, air monitoring will be undertaken at three primary as well as seven satellite sites and one urban background site surrounding Logan and conducted over two separate one-year periods. Combined with the meteorological and other supporting data, a vast amount of information will be collected and assessed.

To distill this material into meaningful information, the data (i.e., individual compound or pollutant category) will be assimilated into summary statistics that are intended to give the reviewers a comprehensive, yet concise, interpretation of the findings. For the target pollutants, the data will be compiled for each site according to the overall highs, lows and average values for the overall sampling period, by day of the week (i.e., Monday, Tuesday, etc.), month (i.e., January, February, etc.), and each 12-month sampling period. For ease in reviewing, the data will be presented both in tabular and graphic (bar-chart) forms.

Wind speed and direction will be summarized in the form of wind roses and temperature and relative humidity in the form of bar-charts showing the range and frequency of values. For the correlation of pollutant levels to meteorological conditions, appropriate statistical comparisons will be developed such as pollutant concentrations versus wind direction and speed. Similar comparisons will be developed depicting airport operational profiles, runway utilization and motor vehicle traffic volumes. In most cases, the summary data will be presented in hard copy and the actual measurement data will be provided in electronic formats.

The continuous PM_{2.5} monitoring data collected at each of the 3 primary sites will be analyzed to provide 24-hour and annual values that will be compared to the PM_{2.5} NAAQS as well as PM_{2.5} monitoring data collected by MADEP at the Harrison Avenue site. PM_{2.5} mini-vol data collected at all primary and satellite stations every 12 days for 24 hours and the PM_{2.5} FRM data collected at the Annavoy Street monitoring station every six days for 24 hours will be compared to the PM_{2.5} 24-hour NAAQS and data collected by the Beta Attenuation Monitors (BAMs) at each of the primary sites and at the MADEP Harrison Avenue site.

The 24-hour VOCs and carbonyl monitoring data will be used to develop annual average concentrations for comparison to data collected at both Harrison Avenue and Lynn monitoring stations.

All of the monitoring results will be quality assured by Massport's consultants based on methods and procedures presented in a separate document called the Quality Assurance Project Plan (QAPP) (See Section 8).

9.6 Data Reporting

Upon completion of the data quality review and data analyses, quarterly reports will be prepared during each 12-month monitoring period. These reports will be made available to MADEP and MADPH for review. A summary report of each monitoring year will also be prepared and made available to MADEP, MADPH and the public through the annual EDR/ESPR process.

Section 10

Roles and Responsibilities

Massport is responsible for overall implementation and completion of the Study. Within Massport, the work is being managed by Keith Beasley, P.E. with oversight by Catherine Wetherell, Director of Environmental Programs. Other key roles taken by Massport staff include Agency Coordination by Betty Derosiers, and the EDR/ESPR Coordination by Jacki Wilkins.

The technical aspects of the Study are being managed by CDM under the direction of Marc Wallace, QEP with oversight by Cynthia Hibbard. Other key contributors include Dr. P. Barry Ryan of the Emory University (Passive Sampling), Dr. John G. Watson of the Desert Research Institute (Active Sampling), George Siple, QEP of CDM, and Mr. Michael A. Kenney, CHMM, QEP, CIH of KB Environmental Sciences, Inc. **Figure 10-1** presents the CDM Project Team organizational chart.

The staffs of MADPH and MADEP will be responsible for reviewing the Work Plan and providing input on air quality monitoring program.

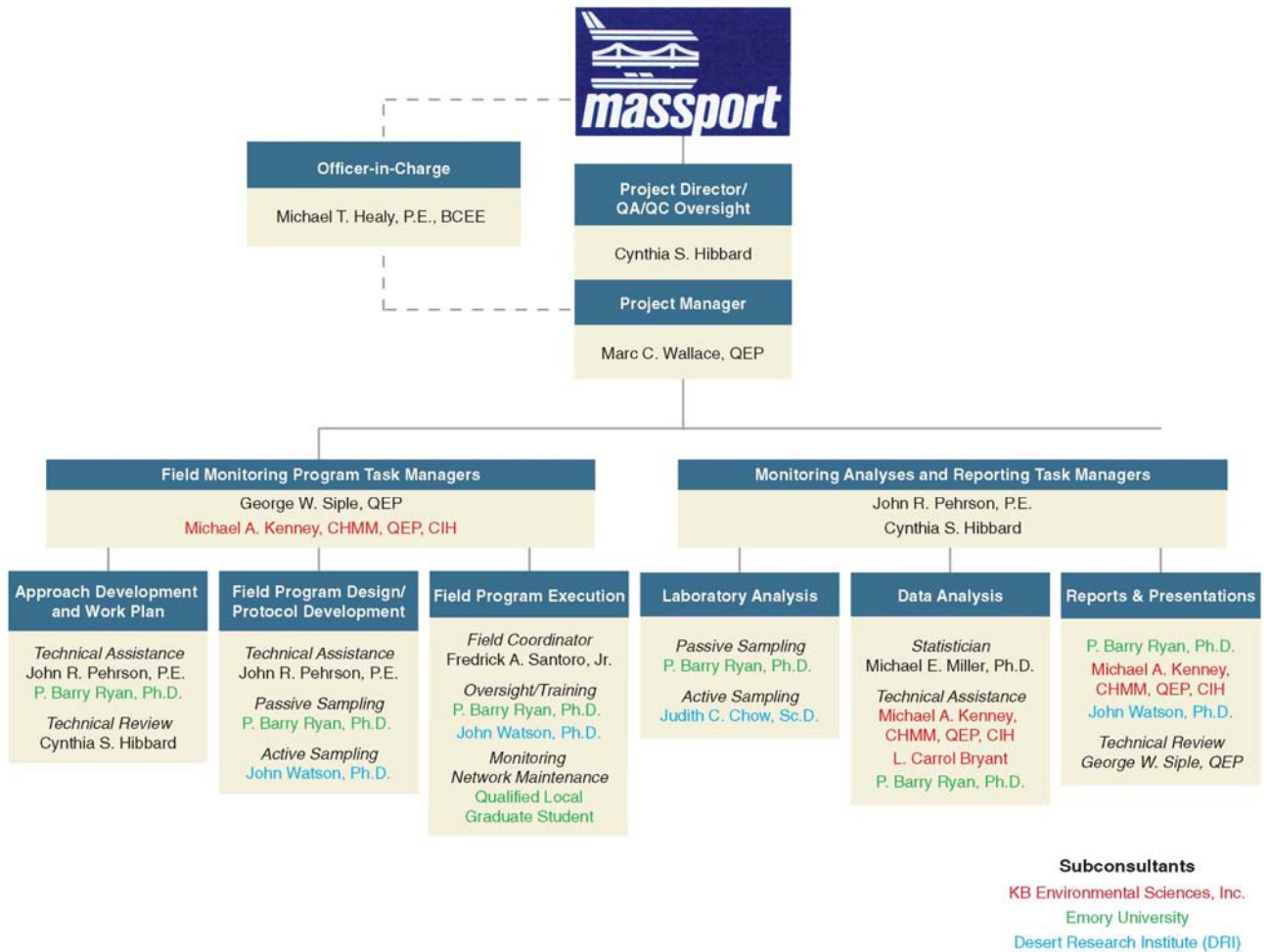


Figure 10-1
CDM Project Team Organizational Chart

Section 11

Schedule

The schedule for completing the baseline year of the Study is presented in **Table 11-1**.

Table 11-1 Baseline Year Air Monitoring Schedule			
Task	Description	Start Date	End Date
1	Prepare Technical Work Plan	Underway	August, 2007
2	Prepare QAPP	April, 2007	August, 2007
3	Procure Field Equipment	April, 2007	May, 2007
4	Setup and Calibrate Equipment	May, 2007	June, 2007
5	Conduct Baseline Monitoring Program	July, 2007	June, 2008
6	Analyze Baseline Monitoring Results	July, 2007	June, 2008
7	Prepare Draft Baseline Monitoring Report	July, 2008	July, 2008

Section 12

References

Flavin, A., *A Neighborhood Representative's Perspective on the Proceedings of the Centerfield Taxiway Evaluation Committee and Recommendations for Environmental Fairness for the People of Winthrop and East Boston*, May 18, 2006.

Massachusetts Department of Environmental Protection, *Meeting with Massachusetts Department of Environmental Protection, CDM, Emory University and Massport, Air Toxics Monitoring Program at Logan International Airport: Background and other Studies*, February 28, 2006.

Massachusetts Department of Public Health, *Meeting with Massachusetts Department of Public Health, CDM, Emory University and Massport, Toxic Air Pollutant Monitoring Plan Development for Logan Airport*, February 10, 2006.

Massachusetts Executive Office of Environmental Affairs, *Certificate of the Secretary of Environmental Affairs of the Final Environmental Impact Report, Logan Airside Improvements Planning Projects*, June 15, 2001.

Select Resource Materials and Annotated Bibliography on the *Topic of Hazardous Air Pollutants Associated with Aircraft, Airports and Aviation*, prepared for the Federal Aviation Administration, July 2003.

U.S. Environmental Protection Agency, *Guidance for Quality Assurance Project Plans (QA/G-5)*, EPA/600/R-98/018, Office of Research and Development, 1998.

U.S. Environmental Protection Agency, *The Original List of Hazardous Air Pollutants*, <http://www.epa.gov/ttn/atw/188polls.html>, downloaded 2006.

U.S. Environmental Protection Agency, *The Green Book of Non-Attainment Areas*, <http://www.epa.gov/oar/oaqps/greenbk/>, 2007.

Vanasse Hangen Brustlin, Inc., *Logan International Airport 2004 Environmental Status and Planning Report (ESPR)* prepared for Massport, 2004.

Vanasse Hangen Brustlin, Inc., *2005 Environmental Data Report, Boston-Logan International Airport*, December 2006.

Appendix A

Site Evaluation Matrix

Logan Airport Air Quality Monitoring Site Evaluation Matrix

Site No./Designation	1	2	3	4	5	6	A	B	C
Site Name	Logan Satellite Fire Station	Logan Fire & Rescue Station	Logan Boat Ramp	Logan Police Canine Bldg.	Logan Runway VOR/Milk Bottle	Logan South Outfall/ Bird Island Flats	Massport @ Annavoy Street	Constitution Beach	Cottage Park Yacht Club
Location/Address	Logan Airport near Runways 22L & 33L	Logan Airport	Logan Airport	Logan Airport	Logan Airport	Logan Airport	Annavoy St. East Boston	East Boston	Orlando Avenue, Winthrop
Contact Information	Logan ARFF Robert Donahue (617) 428-2800	Logan ARFF Robert Donahue (617) 428-2800	FAA	FAA	FAA	FAA	FAA	617-567-9571	Larry Bradley Commodore, 617-846-2792
Views/Photo Nos.									
North	Pic 1: Harbor & Residential	Pic 5 Runway/Airfield	Pic 9: Harbor and Runway	Pic. 13 Airfield Maintenance	Pic. 17 a,b Airfield & Harbor	Pic. 23 Tower, Vent Bldg, Road & Airport Cargo	Pic 27: FAA Bldg, Road, Open Field & Resid.	Pic 31: Rail, Road & Residential	Pic 36: Residential & Road
East	Pic 2: Airfield & Runway	Pic. 6 Runway/Airfield	Pic 10: Harbor and Runway	Pic. 14 Heavy Equip. and Airfield	Pic. 18 Airfield, Harbor & Residential	Pic. 24 Runway, Harbor & Industrial	Pic 28: Open Field, Harbor, Resid. & Comm.	Pic 32: Shoreline, Beach & Resid.	Pic 37: Residential & Shoreline
South	Pic 3: Airfield, Runway & Term.	Pic. 7 Runway/Harbor/ Industrial	Pic 11: Harbor and Runway	Pic. 15 Warehousing and Residential	Pic. 19 Airfield & Harbor	Pic. 25 Harbor & City	Pic 29: Harbor & Airport	Pic 33: Harbor & Airport	Pic 38: Bay & Airport
West	Pic 4: Airfield, Runway & Harbor	Pic. 8 Roadway/Airport Support	Pic 12: Airfield and Terminal	Pic. 16 Airport Terminal	Pic. 20. Airfield Pic. 21 front Pic. 22 back	Pic. 26 Hotel & Harbor	Pic 30: Residential	Pic 34: Boat Storage & Harbor Pic. 35 front	Pic 39: Residential & Airport Pic. 40 NO2 Can
Recorded by	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace
Date	Dec.19 , 2006	Dec.19 , 2006	Dec.19 , 2006	Dec.19 , 2006	Dec.19 , 2006	Dec.19 , 2006	Dec.19 , 2006	Dec.19 , 2006	Dec.19 , 2006
Site Evaluation Criteria									
MEPA Requirements									
Neighborhood	No	No	No	No	No	No	Yes	Yes	Yes
Residential	No	No	No	No	No	No	Yes	Yes	Yes
Under or Near Flight Path	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
Distance/Direction to Centerfield Taxiway	<0.3 miles, E	0.3 miles, E	1 mile, E	1 mile, W	0.9 miles, mile E	0.8 miles W	0.4 miles, N	0.6 miles, NW	0.9 miles, E
Nearby Emission Sources & Influences, except Airport	None	None	None	Near roadway, idling non- road equip. & Logan fuel farm	None	Aldehydes odors from deicing outfall	Surface traffic, residential heating units	Surface traffic, residential heating units	Surface traffic, residential heating units
Upwind/Downwind	Downwind in Winter & Summer	Upwind in Winter & Summer	Downwind in Winter & Summer	Upwind in Winter & neutral in Summer	Downwind in Winter & Summer	Upwind Winter & Summer	Downwind in Summer & neutral in Winter	Upwind in Winter & neutral in Summer	Downwind Winter & Summer
Property Ownership	Massport	Massport	Massport	Massport	Massport	Massport	Massport	City	Cottage Park Yacht Club
Security/Vandalism	Secure Location	Secure Location	Secure Location	Secure Location	Secure Location	Secure Location	Partial fence, some vandalism risk	Low Security	Some security, poss. vandalism risk
FAA Involvement	May require FAA approval.	May require FAA approval.	Requires FAA approval.	May require FAA approval.	Requires FAA approval.	May require FAA approval.	Requires FAA approval.	No	No
Road Access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shelter/Existing Building	Existing Bldg.	Existing Bldg.	Shelter Required	Shelter Required	Existing Bldg.	Shelter Required	Shelter Required	Shelter or Bldg.	Existing Bldg.
Electricity Availability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Site Availability (Short- / Long-term)	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.
Soot and NO ₂ Monitoring Site	No	Yes	No	No	No	Yes	Yes	Yes	Yes
Percentage of Time Under (or Near) Flight Path	<30%	<30%	>50%	<30%	>50%	<30%	30-50%	<30%	<30%
Other Notes				Idling heavy equipment could be a problem.	FAA building could be used.	Aldehydes from deicing chemicals.	2 nd utility pole owned by Massport. Met. station onsite.	Lt. Louis E. Porrazzo Rink	Approval letter from Commodore

Logan Airport Air Quality Monitoring Site Evaluation Matrix

Site No./Designation	D	E	F	G	H	I	J	K	L
Site Name	Winthrop Fire Station	Orient Heights Library	Orient Heights Yacht Club	Pleasant Park Yacht Club	Winthrop Middle School	Coughlin Park	Conley Terminal	MDEP Harrison Avenue Site	North Jetty Site
Location/Address	40 Pauline St Winthrop	18 Barnes Ave East E. Boston, MA	61 Bayswater St East E. Boston	562 Pleasant St Winthrop	151 Pauline St Winthrop	Grandview Road, Winthrop	940 East 1 st Street, South Boston	Harrison & Zeigler	FID Kenndy Ave., South Boston
Contact Information	(617) 846-3474 Winthrop Fire Department	City	(617) 567-9439 townriveryachtclub.com	(617) 846-7124	(617) 846-5507	City or Private Property	Mr. Jim Harris, Massport	MDEP Harrison St. Site	Mr. Jim Harris, Massport
Views/Photo Nos.									
North	Pic 41: School & Pauline St.	Pic 45: Multilane Road & Intersect.	Pic 49: Boat Storage	Pic 54: Road & Residential	Pic 59: Middle School	Pic 63: Bay & Residential	Pic. 69: Port Facility	Pics. 73 - 77	Pic. 78 Harbor & Airport
East	Pic 42: Pauline St. Commercial	Pic 46: Road & Commercial	Pic 50: Road & Residential	Pic 55: Shoreline & Residential	Pic 60: Pauline St. Commercial	Pic 64: Park & Residential	Pic. 70 Port Facility	See above	Pic. 79 Truck Repair Facility, Warehousing & Harbor
South	Pic 43: Fire Station	Pic 47: Residential	Pic 51: Harbor & Airport	Pic 56: Harbor & Airport	Pic 61: Pauline St. & Residential	Pic 65: Road & Residential	Pic. 71 Residential	See above	Pic. 80 Warehousing
West	Pic 44: Pauline St. Commercial	Pic 48: Residential & Const. Beach	Pic 52: Harbor, Comm. & Residential Pic. 53: Front	Pic 57: Boathouse & Beach Pic. 58: front	Pic 62: Residential & Roadway	Pic 66: Harbor & Airport Pic. 67: Noise Mont. Pic. 68: Nearby site	Pic. 72 Port Facility	See above	Pic. 81 Warehousing & City
Recorded by	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace	M. Kenney, M. Wallace
Date	Dec.19, 2006	Dec.19, 2006	Dec.19, 2006	Dec.19, 2006	Dec.19, 2006	Dec.19, 2006	Dec.20, 2006	Dec.20, 2006	Dec.20, 2006
Site Evaluation Criteria									
MEPA Requirements									
Neighborhood	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Residential	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Under or Near Flight Path	No	No	Yes	Yes	No	Yes	Yes	No	Yes
Distance/Direction to Centerfield Taxiway	0.9 miles, E	0.6 miles NW	0.4 miles, NNW	0.6 miles, NE	0.7 miles, E	1.7 miles E.	0.9 miles, S	4 miles, SW	0.7 miles, SW
Nearby Emission Sources & Influences, except Airport	Busy surface road traffic	Busy surface road traffic	Surface traffic, residential heating units	Occasional Tugboat operations	Busy surface road traffic	Surface traffic, residential heating units	Ships & Diesel Equipment	Very busy surface road traffic	Port activities.
Upwind/Downwind	Downwind in Summer & neutral in Winter	Downwind in Summer & neutral in Winter	Downwind in Summer & neutral in Winter	Downwind in Winter & Summer	Downwind in Summer & neutral in Winter	Downwind in Winter & Summer	Upwind Winter & Summer	Upwind Winter & Summer	Upwind in Winter & Summer
Property Ownership	Municipal	Municipal	Orient Heights Yacht Club	Pleasant Park Yacht Club	Municipal	Municipal/Private	Massport	Boston Edison	Massport
Security/Vandalism	Secure Location	Some security, poss. vandalism	Some security, poss. vandalism	Some security, poss. vandalism	Some security, poss. vandalism	Low Security	Secure Location	Secure Location	Secure Location
FAA Involvement	No	No	No	No	No	No	No	No	No
Road Access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shelter/Existing Building	Existing Bldg.	Existing Bldg.	Existing Bldg.	Existing Bldg.	Existing Bldg.	Shelter Required	Existing Bldg.	Existing Shelter	Shelter Required
Electricity Availability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Site Availability (Short- / Long-term)	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.
Soot & NO ₂ Monitoring Site	No	No	Yes	Yes	No	Yes	No	No	No
Percentage of Time Under (or Near) Flight Path	<30%	<30%	30-50%	30-50%	<30%	>50%	>50%	<30%	>50%
Other Notes	Tower with met station	Limited space around bldg	Flat roof bldg , approval letter from Commodore	Approval letter from Commodore		Noise monitor & Open Yard at 27 Grandview Road (Private Property)	Many local sources. Aircraft do not crossover site during takeoffs.	Good site to represent urban backgrd.	Long-term warehouse const. Site away from neighborhood

Logan Airport Air Quality Monitoring Site Evaluation Matrix

Site No./Designation	M	N	O	P	Q	R	S	T
Site Name	Conley Refrigeration Units	MDEP Breman Street Site	Jefferies Cove	Massport – Boston Fish Pier	South Boston Yacht Club	Castle Island	Court Road	Bayswater Street
Location/Address	NE of Conley Terminal (Site X)	Breman St., East Boston	Summer Street, East Boston, MA 02128	Northern Avenue, Boston	1849 Columbia Road, South Boston	William J. Day Blvd, South Boston	93 Court Road	118 Bayswater Street
Contact Information	Jim Harris, Massport	NStar	City of Boston	Massport	Edward Simonds, Commodore (617) 268-6132	City of Boston	Private Property	Private Property
Views/Photo Nos.								
North	Pic. 82 & 85: Harbor & Airport.	Pic. 87: Highway, Comm. & Resid.	Pic. 95: Residential	Pic. 97: Harbor & Airport	Pic. 102: Residential Apts.	Pic. 106: Conley Terminal Wall		Pic. 112: 118 Bayswater St. residence
East	Pic. 83: Harbor Islands	Pic. 88: Fuel Farm & Rt. 1A	Pic. 94: Residential	Pic. 98: Harbor & Airport & Deer Island	Pic. 103: Harbor & Park	Pic. 107: Deer Island WWTP		Pic. 113: Bayswater St. & Winthrop in distance
South	None	Pic. 89: Route 1A & Commercial	None	Pic. 99: Fish Pier & World Trade Center	Pic. 104: Harbor & Islands	Pic. 108: Castle Island Fort	Pic. 111: Court Road neighborhood	Pic. 114: Harbor/ Airport
West	Pic. 84: Trucks Idling and R.U. Bldg.	Pic. 86: Residential	Pic. 96: Residential	Pic. 100: Harbor & City Skyline	Pic. 105: S.B. Yacht Club & Noise Meter	Pic. 109: Castle Island walkway	Pic. 110: Harbor & Airport	Pic. 115: Bayswater St. & Constitution Beach
Recorded by	M. Kenney, M. Wallace	M. Kenney & M. Wallace	M. Kenney	M. Wallace	M. Wallace	M. Wallace	M. Wallace based on discussions with Massport	M. Wallace
Date	Dec. 20, 2006	Dec. 20, 2006	January 5, 2007	January 16, 2007	January 16, 2007	January 25, 2007	April 23, 2007	July 2, 2007
Site Evaluation Criteria								
MEPA Requirements								
Neighborhood	No	Yes	Yes	No	Yes	Yes	Yes	Yes
Residential	No	Yes	Yes	No	Yes	No	Yes	Yes
Under or Near Flight Path	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Distance/Direction to Centerfield Taxiway	0.8 miles S.	1.2 miles, W	1.2 miles, W	1.4 miles, SW	1.9 miles, SSW	1.1 miles, SSE	0.3 miles, E	0.4 miles, N
Nearby Emission Sources & Influences, except Airport	Ships and Diesel Equipment.	Route 1A traffic, commercial & light industrial sources	Surface road traffic	Ships and Diesel Equipment Idling	Busy surface road traffic	Conley Terminal – Idling Diesel Truck Engines	Surface road traffic, residential heating units.	Surface traffic, residential heating units
Upwind/Downwind	Upwind in Winter & Summer	Upwind in Winter & neutral in Summer	Upwind in Summer & Neutral Winter	Upwind in Summer & Neutral Winter	Upwind in Summer & Neutral Winter	Neutral Summer & Winter	Downwind in winter and summer.	Downwind in Summer & neutral in Winter
Property Ownership	Massport	MDEP/NSTAR	East Boston	Massport	South Boston Yacht Club	City of Boston	Private Property	Private Property
Security/Vandalism	Secure Location	Secure Location	Low Security	Secure Location	Some security, poss. vandalism	Low Security	Some security, poss. vandalism	Partial fence, some vandalism risk
FAA Involvement	No	No	No	No	No	No	No	No
Road Access	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shelter/Existing Building	Existing Bldg.	Shelter in place	Shelter Required	Existing Bldg.	Shelter/Existing Bldg. Poss.	Castle Island Fort poss.	Shelter/Existing Bldg. Poss.	Shelter Required
Electricity Availability	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Site Availability (Short- / Long-term)	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.	Available short- and long-term.
Soot & NO ₂ Monitoring Site	No	Yes	Yes	No	No	No	Yes, nearby Loring Road NO ₂ monitor	No
Percentage of Time Under (or Near) Flight Path	>50%	<30%	<30%	>50%	>50%	>50%	30-50%	30-50%
Other Notes		Additional pictures of site (Pics: 90-93)		Abandoned weigh scale buildings for shelters	Massport noise monitoring location, approval letter from Commodore	Additional to Conley Terminal, potential passive monitoring site only		



1. Site 1 Logan Sat. ARFF (N).



2. Site 1 Logan Sat. ARFF (E).



3. Site 1 Logan Sat. ARFF (S).



4. Site 1 Logan Sat. ARFF (W).



5. Site 2 Logan Fire Rescue (N).



6. Site 2 Logan Fire Rescue (E).



7. Site 2 Logan Fire Rescue (S).



8. Site 2 Logan Fire Rescue (W).



9. Site 3 Logan Boat Ramp (N).



10. Site 3 Logan Boat Ramp (E).



11. Site 3 Logan Boat Ramp (S).



12. Site 3 Logan Boat Ramp (W).



17. Site 5 Logan VOR (N).



18. Site 5 Logan VOR (E).



19. Site 5 Logan VOR (S).



20. Site 5. Logan VOR (W).



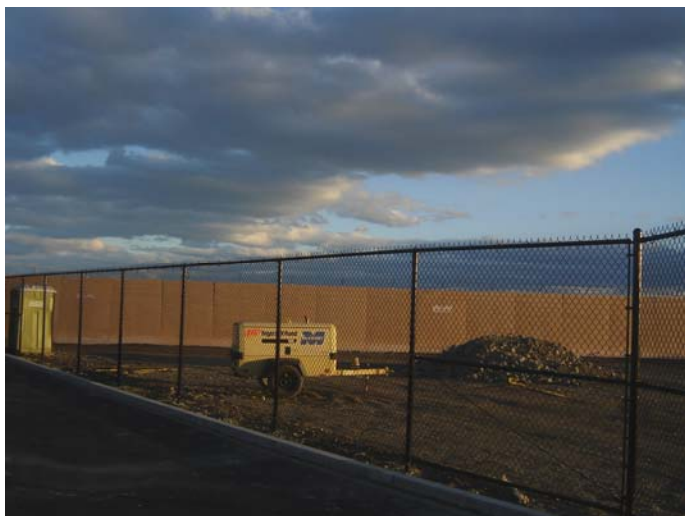
21. Site 5 Logan VOR (front).



22. Site 5 Logan VOR (back).



23. Site 6 Logan S. Outfall (N).



24. Site 6 Logan S. Outfall (E).



25. Site 6 Logan S. Outfall (S).



26. Site 6 Logan S. Outfall (W).



27. Site A Annavoy (N).



28. Site A Annavoy (E).



29. Site A Annavoy (S).



30. Site A Annavoy (W).



31. Site B Const. Beach (N).



32. Site B Const. Beach (E).



33. Site B Const. Beach (S).



34. Site B Const. Beach (W).



35. Site B Const. Beach (front).



36. Site C Cottage Pk. Y.C. (N)



37. Site C Cottage Pk. Y.C. (E)



38. Site C Cottage Pk. Y.C. (S)



39. Site C Cottage Pk. Y.C. (W)



40. Site C Cottage Pk. Y.C. (NOx Can)



41. Site D – Winthrop Fire Station (N).



42. Site D – Winthrop Fire Station (E).



43. Site D – Winthrop Fire Station (S).



44. Site D – Winthrop Fire Station (W).



45. Site E Orient Heights Library (N).



46. Site E Orient Heights Library (E).



47. Site E Orient Heights Library (S).



48. Site E Orient Heights Library (W).



49. Site F Orient Hts. Y.C. (N).



51. Site F Orient Hts. Y.C. (S).



52. Site F Orient Hts. Y.C. (W).



50. Site F Orient Hts. Y.C. (E).



53. Site F Orient Hts. Y.C. (front).



54. Site G Pleasant Pk. Y.C. (N).



55. Site G Pleasant Pk. Y.C. (E).



56. Site G Pleasant Pk. Y.C. (S).



57. Site G Pleasant Pk. Y.C. (W).



58. Site G Pleasant Pk. Y.C.



59. Site H – Winthrop Middle School (N).



60. Site H – Winthrop Middle School (E).



61. Site H – Winthrop Middle School (S).



62. Site H – Winthrop Middle School (W).



63. Site I Coughlin Pk. (N).



64. Site I Coughlin Pk. (E).



65. Site I Coughlin Pk. (S).



66. Site I Coughlin Pk. (W).



68. Site I Coughlin Pk. (Alt. Site).



67. Site I Coughlin Pk. (Noise Mont.).



69. Site J Conley Term. (N).



70. Site J Conley Term. (E).



71. Site J Conley Term. (S).



72. Site J Conley Term. (W).



73. Site K MDEP Harrison (1).



74. Site K MDEP Harrison (2).



75. Site K MDEP Harrison (3).



76. Site K MDEP Harrison (4).jpg



77. Site K MDEP Harrison (5).



78. Site L N. Jetty (N).



79. Site L N. Jetty (E).



80. Site L N. Jetty (S).



82. Site L N. Jetty (W).



82. Site M Conley Refrig. Units (N).



83. Site M Conley Refrig. Units (E).



84. Site M Conley Refrig. Units (S).



85. Site M Conley Refrig. Units (W).



87. Site N Breman St. (N).



88. Site N Breman St. (E).



89. Site N Breman St. (S).



86. Site N Breman St. (W).



90. Site N Breman St. (front).



91. Site N Breman St. (NStar 1).



92. Site N Breman St. (NStar 2).



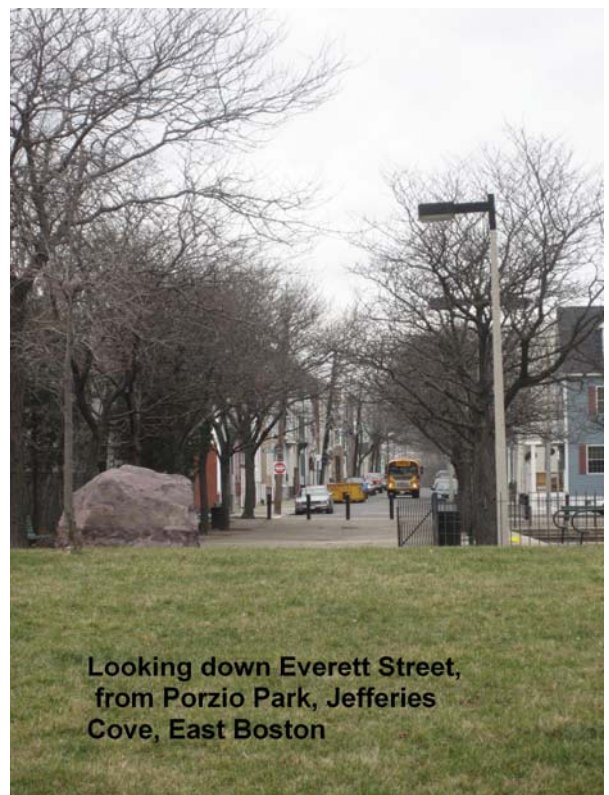
93. Site N Breman St. (side view).



94. Site O – Jefferies Cove (E).



95. Site O – Jefferies Cove (N).



96. Site O – Jefferies Cove (W).



97. Site P Fish Pier (N).



98. Site P Fish Pier (E).



99. Site P Fish Pier (S).



100. Site P Fish Pier (W).



101. Site P Fish Pier – Scale House



102. Site Q – S. Boston Yacht Club (N).



103. Site Q – S. Boston Yacht Club (E).



104. Site Q – S. Boston Yacht Club (S).



105. Site Q – S. Boston Yacht Club (W).



106. Site R – Castle Island (N).



107. Site R – Castle Island (E).



108. Site R – Castle Island (S).



109. Site R – Castle Island (W).



110. Site S – Court Road (W).



111. Site S – Court Road (S).



112. Site T – Bayswater St. (N).



113. Site T – Bayswater St. (E).



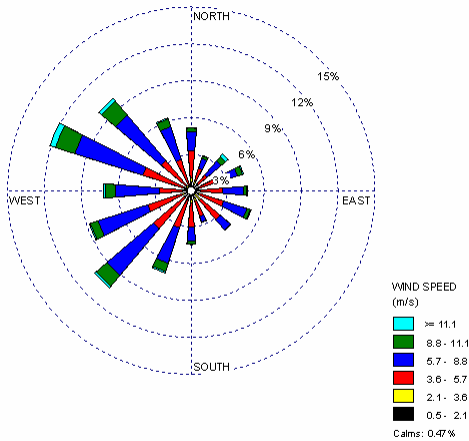
114. Site T – Bayswater St. (S).



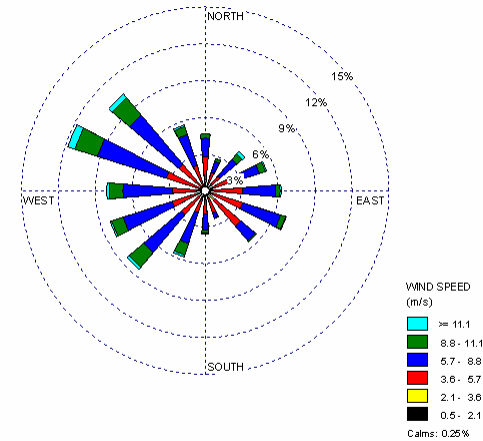
115. Site T – Bayswater St. (W).

Appendix B

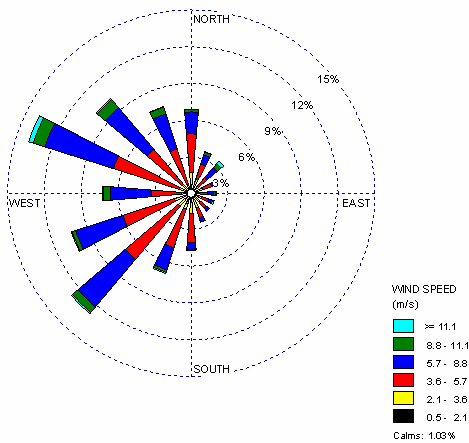
Logan Airport Windroses



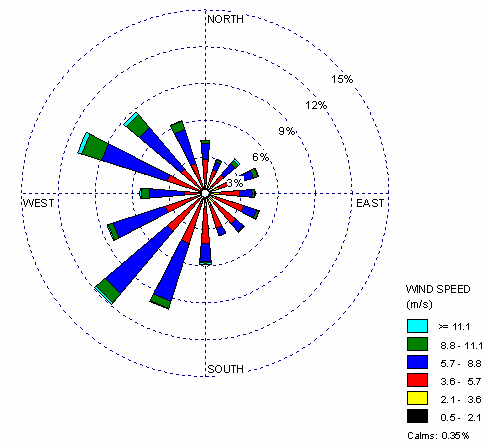
**Boston Logan International Airport Annual
Average Wind Speed 5.77 m/s**



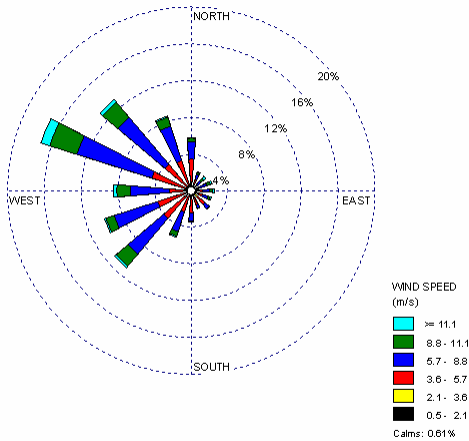
**Boston Logan International Airport Annual Day
Average Wind Speed 6.11 m/s**



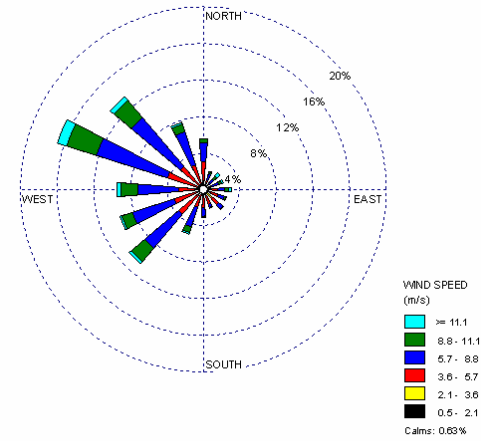
**Boston Logan International Airport Annual Morning
Average Wind Speed 5.16 m/s**



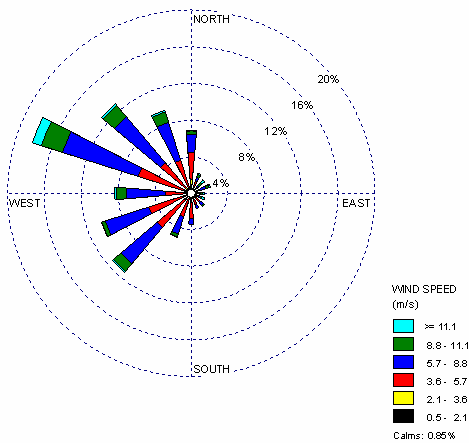
**Boston Logan International Airport Annual Evening
Average Wind Speed 5.67 m/s**



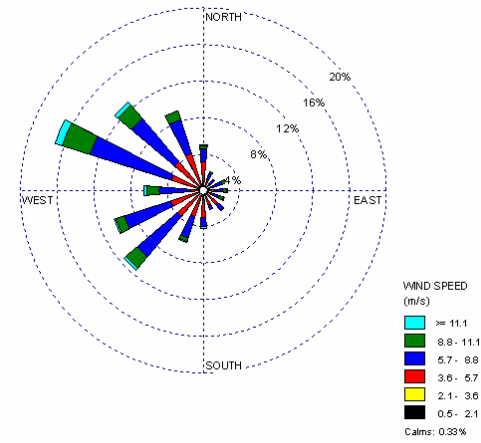
Boston Logan International Airport Winter
Average Wind Speed 6.21 m/s



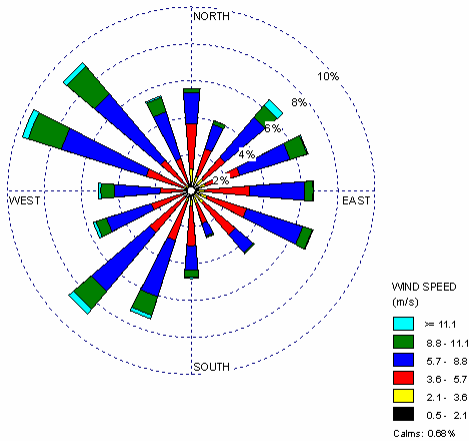
Boston Logan International Airport Winter Day
Average Wind Speed 6.34 m/s



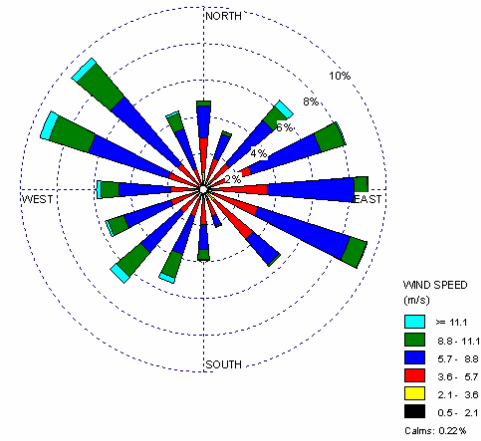
Boston Logan International Airport Winter Morning
Average Wind Speed 5.93 m/s



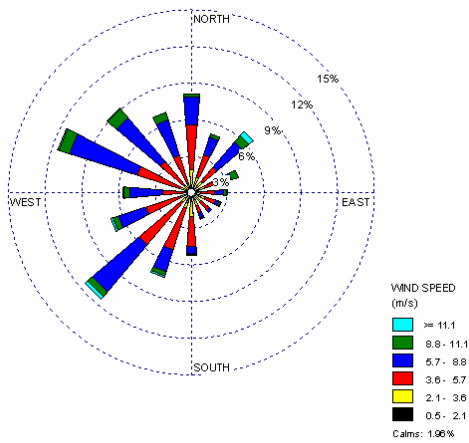
Boston Logan International Airport Winter Evening
Average Wind Speed 6.20 m/s



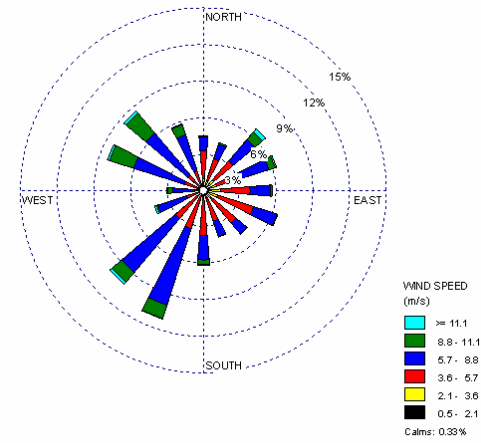
Boston Logan International Airport Spring
Average Wind Speed 5.99 m/s



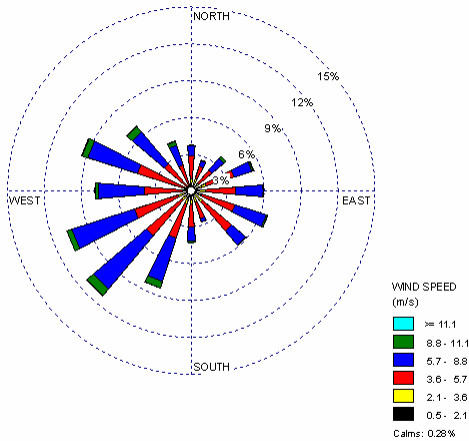
Boston Logan International Airport Spring Day
Average Wind Speed 6.44 m/s



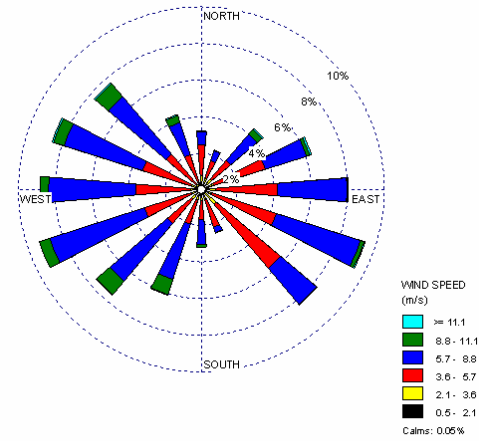
Boston Logan International Airport Spring Morning
Average Wind Speed 5.24 m/s



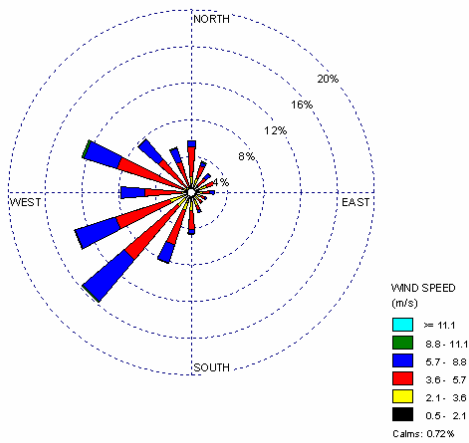
Boston Logan International Airport Spring Evening
Average Wind Speed 5.85 m/s



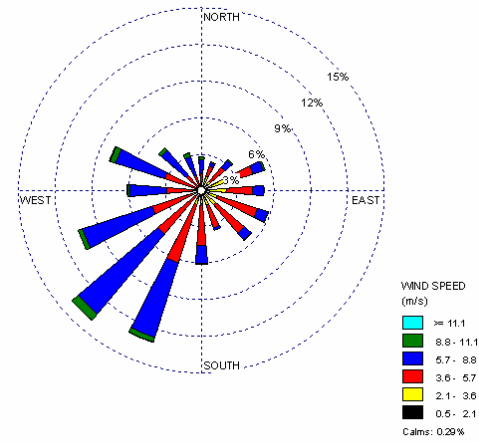
Boston Logan International Airport Summer
Average Wind Speed 5.25 m/s



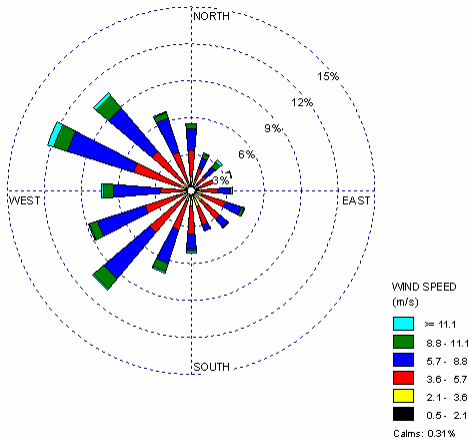
Boston Logan International Airport Summer Day
Average Wind Speed 5.65 m/s



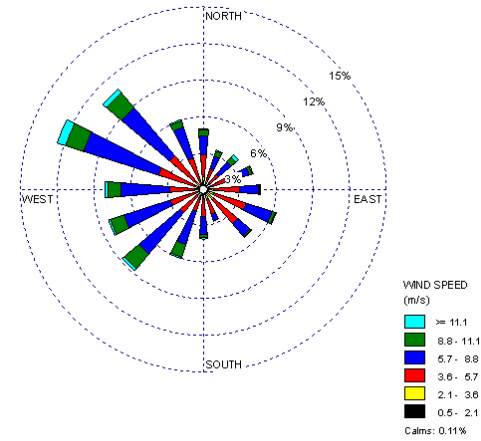
Boston Logan International Airport Summer Morning
Average Wind Speed 4.53 m/s



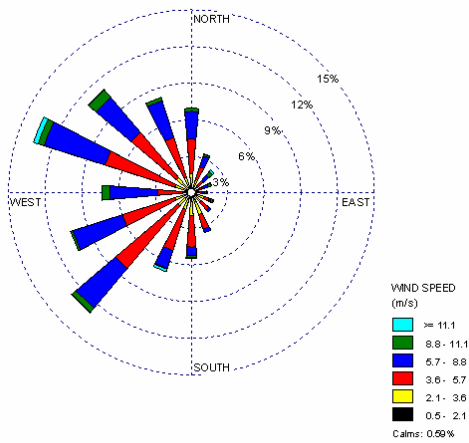
Boston Logan International Airport Summer Evening
Average Wind Speed 5.16 m/s



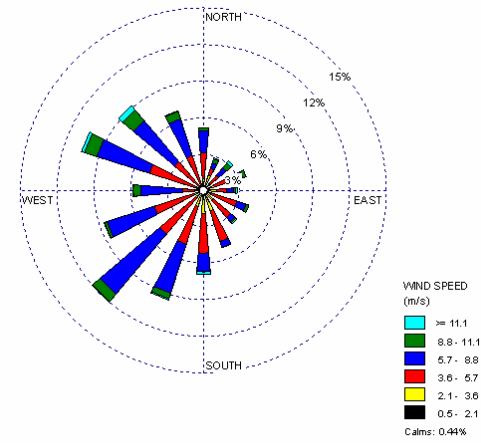
Boston Logan International Airport Fall
Average Wind Speed 5.62 m/s



Boston Logan International Airport Fall Day
Average Wind Speed 5.99 m/s



Boston Logan International Airport Fall Morning
Average Wind Speed 5.05 m/s



Boston Logan International Airport Fall Evening
Average Wind Speed 5.47 m/s

Appendix C

Soot and NO₂ Monitoring Stations



Massport—Logan Air
Monitoring Study

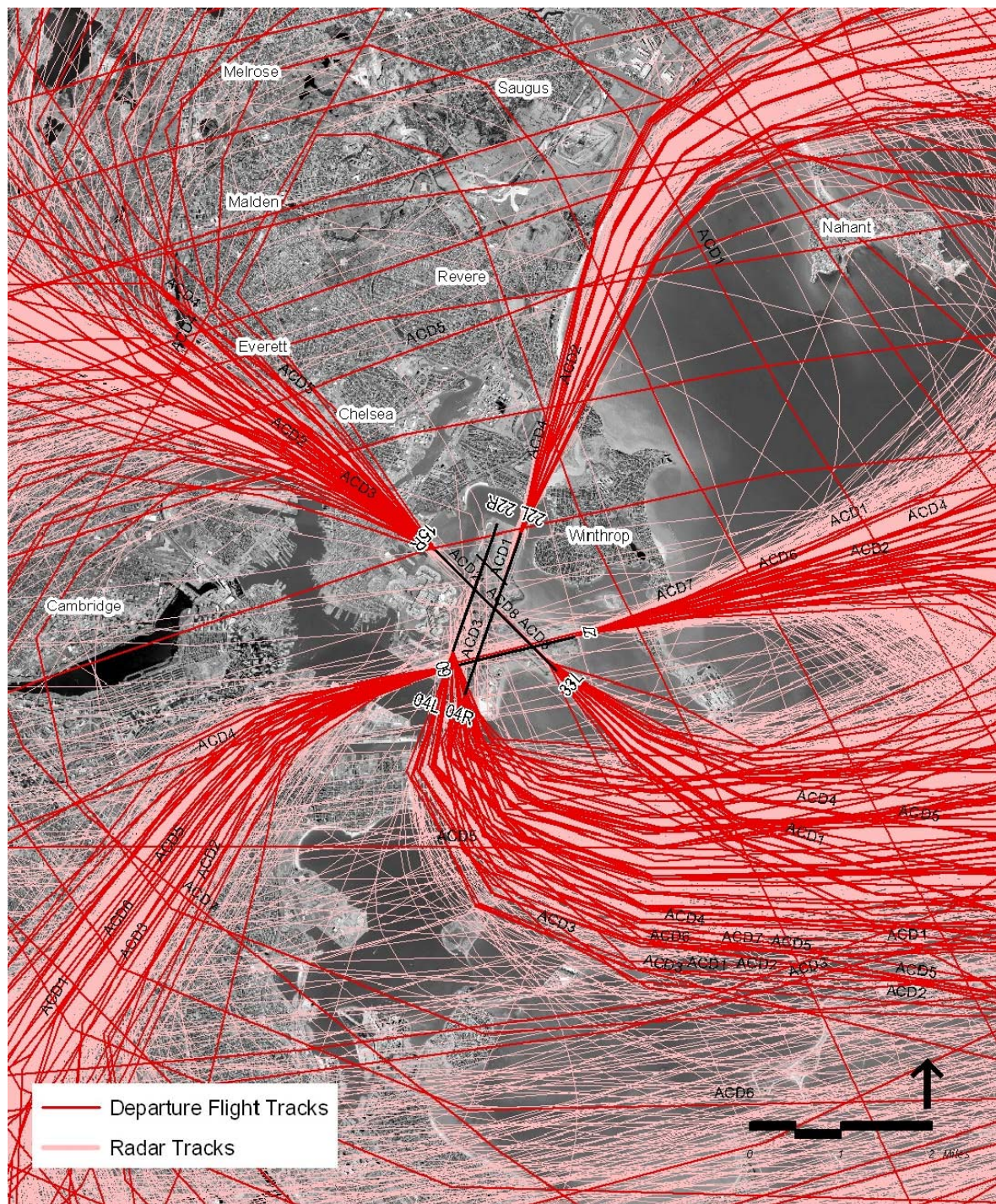
Figure C-1
Soot and NO₂
Monitoring Sites

Appendix D

ESPR 2004 Air Carrier Flight Paths

2004 ESPR
LOGAN INTERNATIONAL AIRPORT

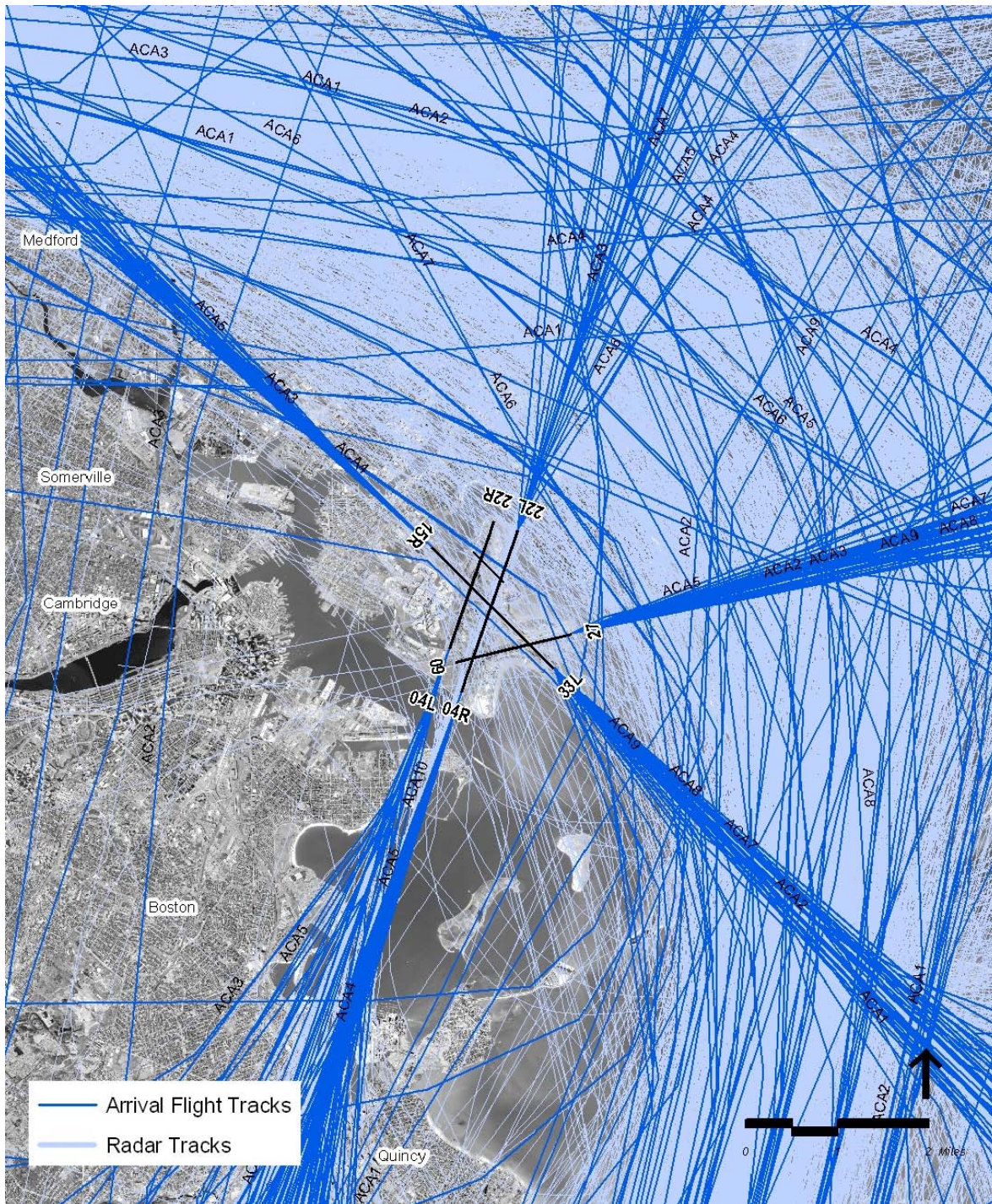
Figure D-1 Air Carrier - Departure Flight Tracks



Source: Massport, 2004 Logan International Airport Environmental Survey and Planning Report, Appendix H - Noise, 2004.

2004 ESPR
LOGAN INTERNATIONAL AIRPORT

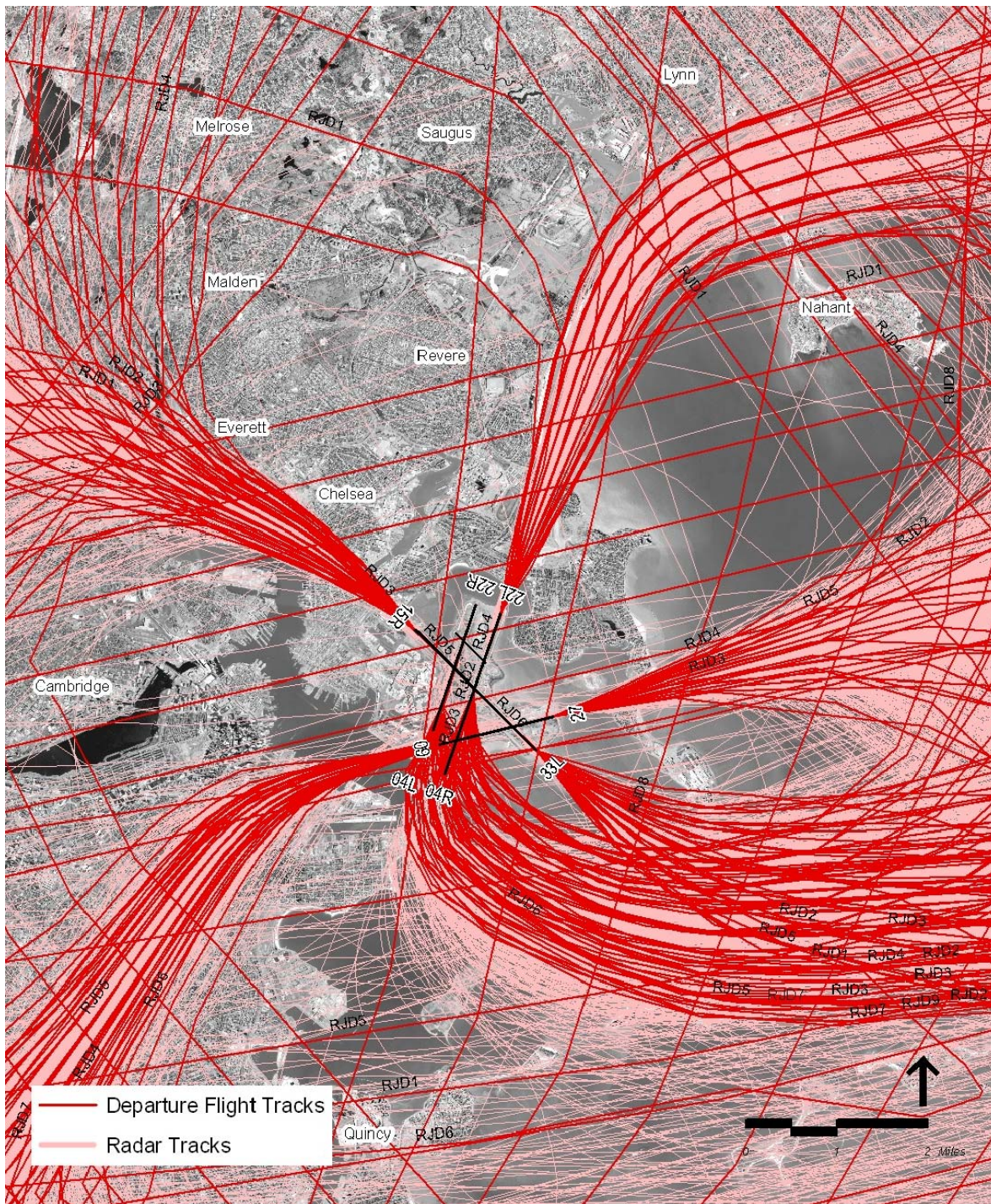
Figure D-2 Air Carrier - Arrival Flight Tracks



Source: Massport, 2004 Logan International Airport Environmental Survey and Planning Report, Appendix H - Noise, 2004.

2004 ESPR
LOGAN INTERNATIONAL AIRPORT

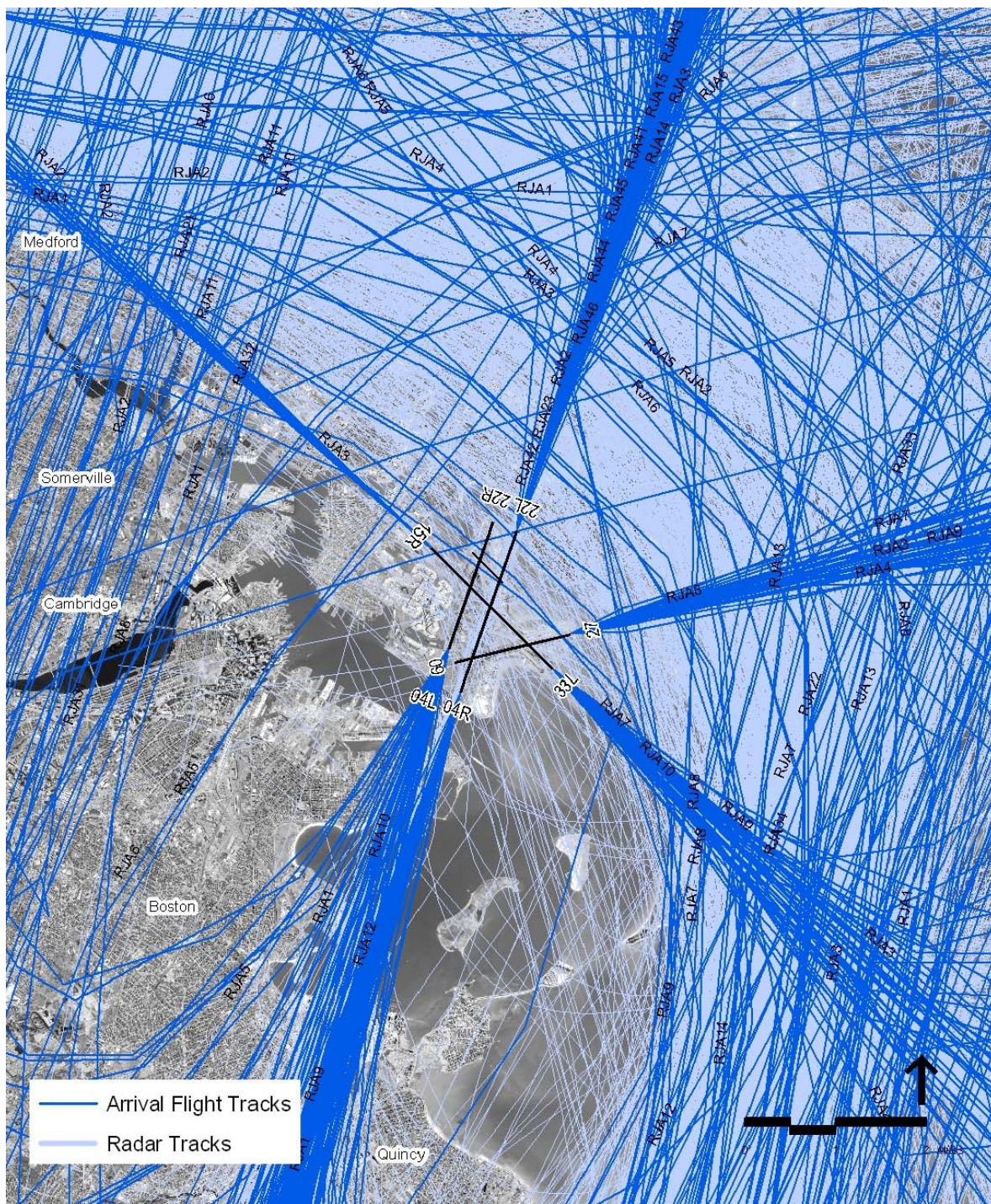
Figure D-3 Regional Jet - Departure Flight Tracks



Source: Massport, 2004 Logan International Airport Environmental Survey and Planning Report, Appendix H - Noise, 2004.

2004 ESPR
LOGAN INTERNATIONAL AIRPORT

Figure D-4 Regional Jet - Arrival Flight Tracks



Source: Massport, 2004 Logan International Airport Environmental Survey and Planning Report, Appendix H - Noise, 2004.

Appendix E

White Paper - The Use of Passive Samplers in Conjunction with the Logan International Airport Air Quality Monitoring Study

A Bibliography of Passive Monitoring Methods Used in the Logan International Airport Air Quality Monitoring Study

Citations Available in pdf Format

These citations give a useful overview of passive monitoring in general (See Brown), and descriptions and applications of each of the types of monitoring selected for the air quality passive monitoring program. This set offers a concise overview of the field and of the sampling strategies that we are employing.

Brown, R. (2000). "Monitoring the ambient environment with diffusive samplers: theory and practice/." Journal of Environmental Monitoring 2(1): 1-9

Fan, Z., K. Jung, et al. (2006). "Development of a passive sampler to measure personal exposure to gaseous PAHs in community settings." Environmental Science & Technology 40(19): 6051-6957.

Liu W, Zhang J, Zhang L, Turpin BJ, Weisel CP, Morandi MT, Stock TH, Colome C Korn LR. (2006) Estimating contributions of indoor and outdoor sources to indoor carbonyl concentrations in three urban areas of the United States. Atmospheric Environment 40 2202-2214

Liu W, Zhang J, Kwon J, Weisel C, Turpin B, Zhang L, Morandi M, Stock T, Colome S. (2006) Concentrations and Source Characteristics of Airborne Carbonyl Compounds Measured Outside Urban Residences J. Air & Waste Manage. Assoc. 56 1196-1204

Pratt, G., D. Bock, et al. (2005). "A Field Comparison of Volatile Organic Compounds Using Passive Organic Vapor Monitors and Stainless Steel Canisters." Environmental Science & Technology 39(9): 3261-3268.

Zhang, J., L. Zhang, et al. (2000). "Development of the Personal Aldehydes and Ketones Sampler Based Upon DNSH Derivatization on a Solid Sorbent." Environmental Science & Technology 34(12): 2601-2607.

Citations from the Passive Monitoring White Paper

These are all the citations from the passive monitoring White Paper. Most are available online and all are available in libraries. They represent a cross section of papers using passive monitoring for community studies and environmental epidemiology as well as descriptive papers outlining passive sampling in general and specific types of samplers. These papers are a subset of the full, annotated bibliography found as an Appendix to the White Paper.

3M. (2007). "Technical Data Bulletin: Organic Vapor Monitor Sampling and Analysis Guide." from <http://multimedia.mmm.com/mws/mediawebserver.dyn?6666660Zjcf6lVs6EVs666CswCOrrrrQ-> [Accessed 16 February 2007].

- Ayres, M. and P. Ryan (2006). A Longitudinal Study of Nitrogen Dioxide Concentrations around a Major Metropolitan Airport: 1987 – 2005. P. Barry Ryan and Megan M. Ayres. . Joint Annual Meeting of the International Society of Exposure Analysis and International Society for Environmental Epidemiology. Paris, France.
- Brown, R. (2000). "Monitoring the ambient environment with diffusive samplers: theory and practice/." Journal of Environmental Monitoring 2(1): 1-9.
- Brunekreef, B., D. Houthuijs, et al. (1990). "Indoor Nitrogen-Dioxide Exposure and Childrens Pulmonary-Function." Journal of the Air & Waste Management Association 40(9): 1252-1256.
- Cohen, M. A., P. B. Ryan, et al. (1991). "Source Receptor Study of Volatile Organic Compounds and Particulate Matter in the Kanawha Valley, WV .2. Analysis of Factors Contributing to VOC and Particle Exposures." Atmospheric Environment Part B-Urban Atmosphere 25(1): 95-107.
- Cohen, M. A., P. B. Ryan, et al. (1990). "The Validation of a Passive Sampler for Indoor and Outdoor Concentrations of Volatile Organic Compounds." Journal of the Air & Waste Management Association 40(7): 993-997.
- Cohen, M. A., P. B. Ryan, et al. (1989). "Indoor Outdoor Measurements of Volatile Organic-Compounds in the Kanawha Valley of West Virginia." IAPCA 39(8): 1086-1093.
- Draeger. (2007). from http://www.draeger.com/ST/internet/US/en/Products/Detection/Drager-Tubes/draeger_tubes.jsp [Accessed 16 February 2007].
- Fan, Z., K. Jung, et al. (2006). "Development of a passive sampler to measure personal exposure to gaseous PAHs in community settings. ." Environmental Science & Technology 40(19): 6051-6957.
- Florey, C. D. V., R. J. W. Melia, et al. (1979). "Relation between Respiratory Illness in Primary School Children and the Use of Gas for Cooking .3. Nitrogen Dioxide, Respiratory Illness and Lung Infection." International Journal of Epidemiology 8(4): 347-353.
- Melia, R. J., S. Chinn, et al. (1979). "Relationship between Indoor Air Pollution from Nitrogen Dioxide and Respiratory Illness in Primary School Children." Journal of Epidemiology and Community Health 33(2): 164-164.
- Melia, R. J. W., C. D. Florey, et al. (1982). "Childhood Respiratory Illness and the Home Environment .1. Relations between Nitrogen Dioxide, Temperature and Relative Humidity." International Journal of Epidemiology 11(2): 155-163.
- Melia, R. J. W., C. D. Florey, et al. (1982). "Childhood Respiratory Illness and the Home Environment .2. Association between Respiratory Illness and Nitrogen Dioxide,

- Temperature and Relative Humidity." International Journal of Epidemiology 11(2): 164-169.
- Melia, R. J. W., C. D. V. Florey, et al. (1980). "Relation between Indoor Air Pollution from Nitrogen Dioxide and Respiratory Illness in Primary School Children." Bulletin Europeen De Physiopathologie Respiratoire-Clinical Respiratory Physiology 16(1): P7-P8.
- Palmes, E. and A. Gunnison (1973). "Personal monitoring device for gaseous contaminants." American Industrial Hygiene Association Journal 34: 78-81.
- Pratt, G., D. Bock, et al. (2005). "A Field Comparison of Volatile Organic Compounds Using Passive Organic Vapor Monitors and Stainless Steel Canisters." Environmental Science & Technology 39(9): 3261-3268.
- Ryan, P. B., M. L. Soczek, et al. (1988). "The Boston Residential NO₂ Characterization Study .1. Preliminary Evaluation of the Survey Methodology." Iapca-the International Journal of Air Pollution Control and Hazardous Waste Management 38(1): 22-27.
- Ryan, P. B., M. L. Soczek, et al. (1988). "The Boston Residential NO₂ Characterization Study .2. Survey Methodology and Population Concentration Estimates." Atmospheric Environment 22(10): 2115-2125.
- Ryan, P. B., J. D. Spengler, et al. (1983). "The Effects of Kerosene Heaters on Indoor Pollutant Concentrations - a Monitoring and Modeling Study." Atmospheric Environment 17(7): 1339-1345.
- Spengler, J., M. Schwab, et al. (1994). "Personal Exposure to Nitrogen Dioxide in the Los Angeles Basin." Journal of the Air & Waste Management Association 44(1): 39-47.
- Spengler, J. D., B. G. Ferris, et al. (1979). "Sulfur Dioxide and Nitrogen Dioxide Levels Inside and Outside Homes and the Implications on Health-Effects Research." Environmental Science & Technology 13(10): 1276-1280.
- Zhang, J., L. Zhang, et al. (2000). "Development of the Personal Aldehydes and Ketones Sampler Based Upon DNSH Derivatization on a Solid Sorbent." Environmental Science & Technology 34(12): 2601-2607.

The Use of Passive Samplers in Conjunction with the Logan Air Quality Monitoring Study

P. Barry Ryan, Emory University

February 21, 2007

History and Usage of Passive Monitors Use

The use of passive samplers for air contaminant monitoring has a long history. Passive samplers have been used for monitoring a wide range of pollutants at a variety of locations over the past 30 years. In recent years, passive samplers have been used more progressively for research, public health investigations and by regulatory agencies for addressing compliance with ambient air quality standards in the United States and Europe. For more details, Brown (Brown 2000) gives a brief history of passive sampling. Some of the highlights are noted below.

The first passive samplers used in industrial settings were the tube-type Palmes sampler discussed above to monitor for sulfur dioxide and nitrogen dioxide. A preliminary report on this sampler appeared as early as 1973 (Palmes and Gunnison 1973). In the early 1980s, passive samplers for volatile organic compounds--essentially the 3M OVM 3500 sampler--began to be used extensively. This sampler, and other similar samplers that monitored for formaldehyde and other trace gases in occupational settings, was used extensively to measure personal exposures to these contaminants experienced by workers in occupational environments.

Commencing in the late 1970s, academic researchers began using passive sampling in the community settings. Spengler and co-workers at Harvard School of Public Health implemented an indoor-outdoor network of nitrogen dioxide monitors using the Palmes samplers as part of the long-term epidemiologic study of lung health known as the Harvard Six-Cities Study (Spengler, Ferris et al. 1979). In this work, passive samplers were placed inside and outside the homes of 50 individuals in each of the six cities for one-week periods. Their use proved effective in estimating exposures to nitrogen dioxide experienced by individuals in the community. Passive sampling for nitrogen dioxide using these samplers became quite common in Europe throughout the 1980s as well. Brunekreef in the Netherlands (Brunekreef, Houthuijs et al. 1990) and Melia in the United Kingdom (Florey, Melia et al. 1979; Melia, Chinn et al. 1979; Melia, Florey et al. 1980; Melia, Florey et al. 1982; Melia, Florey et al. 1982) did extensive work evaluating air pollution epidemiology using these samplers. Commencing in 1985 and continuing through 1986, Spengler and co-workers (Ryan, Spengler et al. 1983; Ryan, Soczek et al. 1988; Ryan, Soczek et al. 1988; Spengler, Schwab et al. 1994) at Harvard performed a longitudinal study of exposures to nitrogen dioxide experienced by a representative sample of over 500 individuals in the Boston standard metropolitan statistical area using Palmes samplers. Ryan and co-workers have used these samplers to investigate community nitrogen dioxide concentrations in the East Boston and Winthrop communities around Logan International Airport since 1982 (Ayres and Ryan 2006). In this study, long-term downward trends in the level of this contaminant have been documented in the community through the use of these simple samplers.

Commencing in the late 1980s with work by Ryan and co-workers at Harvard School of Public Health (Cohen, Ryan et al. 1989; Cohen, Ryan et al. 1990; Cohen, Ryan et al. 1991), passive sampling for volatile organic compounds in community settings has been undertaken. Using the 3M OVM 3500 sampler designed initially for occupational settings (and used extensively in such locations) these researchers validated the samplers for long-duration sampling under community-level exposure conditions. After validation, they performed a

longitudinal investigation of indoor and outdoor VOC concentrations in an industrial community in and around Charleston, West Virginia.

Consolidation/summary of literature references by pollutant monitored

Since the mid 1990s, there has been an explosion in the use of passive samplers in community settings. However, there still remain concerns about the use of such samplers in studies based in the community. To address some concerns regarding the acceptance of passive samplers as a method of collection for environmental contaminants in community settings by the general scientific community, project team member Dr. John Watson of the Desert Research Institute performed a literature search. The result of this literature review is appended to this document as **Appendix I**. The literature review found 164 peer-reviewed publications that discuss passive sampler use in environmental and occupational monitoring. The annotated literature search includes citations and, in most cases, the Abstract for each paper. Many of these papers describe new samplers, but most describe the application of passive samplers in non-occupational monitoring settings. Additionally, most of the papers describing new samplers also include a validation component in which the results from the samplers are compared with results from commonly accepted methods, including active sampling (see **Methods Validation** section.) Indeed a few of the papers focus solely on this issue. It is worthy of note that the number of papers published each year on this subject has increased dramatically in the last few years suggesting a greater interest in and a more general acceptance of these procedures by the scientific community. Michael Kenney and co-workers have produced a summary table summarizing these investigations. This is attached as **Appendix II** to this document.

Passive Monitoring for Air Contaminants

Passive samplers operate under the general principle that chemical compounds move from regions of high concentration to regions of low concentration by means of diffusion. This principle is common experience; air fresheners, for example, release fragrance from a source (high concentration) and diffuse throughout a room (low concentration.) This difference in concentration is referred to as a *concentration gradient*. A concentration gradient is set up in a passive sampler by introducing into the sample an *absorbing medium*, a material that effectively and selectively removes the compound of interest from the air. At the surface of the absorbing medium, the concentration of the contaminant is zero. Away from the absorbing medium, the concentration is greater than zero resulting in the required concentration gradient. The movement of material toward the absorbing surface is proportional to the concentration gradient, with the constant of proportionality called the diffusion coefficient. Brown (Brown 2000) offers an excellent description of the theory and practical considerations associated with passive sampling. The reader is referred to this paper for further discussion. His work is summarized here.

Tube-Type Passive Samplers

The simplest type of passive sampler makes use of a cylindrical tube, with one enclosed end. A schematic of such a sampler is depicted in Figure 1. The concentration is zero at that point setting up the concentration gradient and is assumed to decrease linearly from the ambient concentration at the mouth of the sampler to zero at the surface of the absorbing medium. The samplers are returned to the laboratory where they are analyzed to determine the amount of collected material quantitatively. Knowledge of the physical configuration of the sampler, in particular the cross-sectional area of the samplers and the length of the diffusion gradient, coupled with information on the sampling duration and the diffusion coefficient for the sampled gas affords quantification of the average concentration of air contaminant seen by the sampler during its deployment.

Figure 1. Schematic of a typical tube-type passive sampler. The concentration of the monitored contaminant is represented by ρ . ρ_1 is the concentration in the ambient air. ρ_2 is the concentration at the surface of the sorbent, generally assumed to be zero. D is the cross-sectional area of the tube. l is the diffusion length. Figure taken from Brown, RH. *Monitoring the ambient environment with diffusive samplers: theory and practical considerations*. *J. Environ Monitoring* 2000. 2 (1-9).

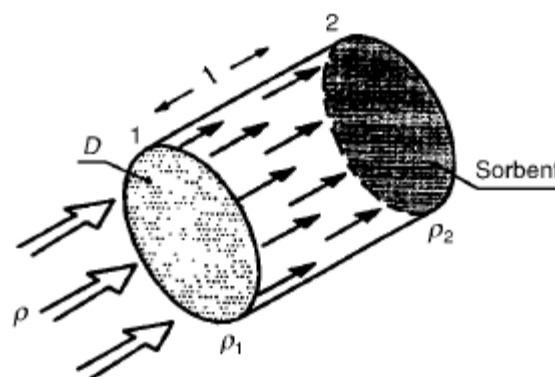
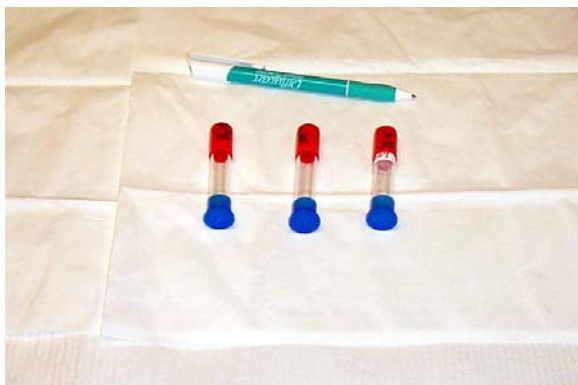


Fig. 1 Diagram of diffusion process.

The Palmes sampler for nitrogen dioxide (Palmes and Gunnison 1973), three of which are shown in **Figure 2**, illustrate this type of sampler. This sampler is fabricated from a clear acrylic tube and two plastic caps one on either end. One of these caps, the flanged cap on the lower end, is removable, while the other remains fixed during sampling. The absorbing medium, triethanolamine, or TEA, is coated onto stainless steel screens placed in the fixed cap prior to insertion of the tube. When the removable (flanged) cap is removed, nitrogen dioxide contained in air diffuses down the tube until it encounters the absorbing medium, TEA, and is removed. **Appendix III** describes the physics and mathematics in more detail.

Figure 2. Palmes samplers. An example of a tube-type passive sampler.



All passive samplers of the tube type operate by identical principles. For example, the Zhang sampler for aldehydes (Zhang, Zhang et al. 2000) uses a similar design with a removable cap (**See Figure 3**). The absorbing medium in this case is a C18 solid-phase extraction cartridge coated with dansyl hydrazine. Dansyl hydrazine reacts selectively with carbonyl-containing molecules, including aldehydes, to form a stable adduct thereby removing the aldehydes from the air stream and effecting a concentration gradient.

The Zhang sampler differs from the Palmes sampler in that it uses a different absorbing medium, one selective for aldehydes, and that it monitors for several compounds at once. Laboratory analytical procedures are, of course, different.

Diffusion-Barrier Passive Samplers

While tube-type samplers all operate under the same principal and theoretical calculations lead to quantitatively accurate results, alternative methods can be used as well. The 3M OVM 3500 (3M 2007) passive sampler for volatile organic compounds (VOCs) (see Figure 3) uses a diffusion barrier, rather than the cylindrical tube, to effect the concentration gradient.

In this configuration, a semi-permeable membrane (the white, circular plastic sheet covering most of the surface of the OVM sampler on the right) sets up the diffusion barrier. Beneath the membrane is the absorbing medium, in this case charcoal, that effectively removes the compound from the air stream. One cannot rely on theory for the sampling rate of such devices. The manufacturer tests these devices under numerous conditions in chamber settings and determines the effective sampling rate, which is then supplied to the user. The OVM sampler collects various volatile organic compounds quantitatively on the charcoal absorbent commencing when the cap (not shown) is removed. As in the case of the other passive samplers, the sampler is re-capped at the end of sampling, the time noted, and the sampler is returned to the laboratory for analysis.

Figure 3. The Zhang passive sampler for aldehydes (a tube-type passive sampler, on left) and the 3M OVM 3500 sampler (a diffusion barrier type, on right) from volatile organic compounds. In “sampling” configuration.



Absorbing Media for Passive Sampling

In this presentation, we have alluded to various types of “absorbing media”--TEA for nitrogen dioxide, dansyl hydrazine for carbonyl-containing materials, and charcoal for VOCs. More detail is given on these media.

The essential requirement for an absorbing medium in passive sampling is that it quickly and quantitatively reacts with the compound to be collected effectively removing it from the air stream (Brown 2000).

Quantitative removal from the air stream resulting in zero concentration at the surface of the absorbing medium is required to set up the concentration gradient under all concentration conditions. For most passive samplers, this is done by reacting the compound to be collected with some material that produces a stable molecular adduct that is non-volatile and stays bound to the surface of the support for the medium. As an example, for nitrogen dioxide, triethanolamine reacts directly with nitrogen dioxide in the air to form a nitrate salt in a generalized acid-base reaction. The salt, essentially triethanolamine nitrate, is stable and non-volatile. For the Zhang sampler, dansyl hydrazine condenses with the specific carbonyl compound being monitored to form the specific hydrazone. This is, again, a stable compound with no volatility.

For the VOC sampler, no chemical reaction takes place. Rather, the VOC is adsorbed onto the surface of the charcoal by a process called chemisorbtion. The bonds formed are relatively weak, but are strong enough to hold the material in place and reduce its volatility, and thus concentration in air, to zero. In contrast to the Palmes and Zhang samplers where the adduct itself is measured to quantify the amount of material collected, for the VOC samplers, the actual compound is liberated in the laboratory for analysis.

Other absorbing media can be used as well. For the Fan-Lioy PAH sampler (Fan, Jung et al. 2006), for instance, gas chromatography columns with an interior polymer coating as an absorbing medium are used. Similarly, other types of VOC samplers, particularly those designed for specific compounds, use a polymer

coating on a silica substrate to trap the material using a process called physisorption. Drager tubes (Draeger 2007), which are usually operated in an active mode, can also be used passively. Like the Zhang samplers, they use chemically treated silica substrates in which the chemically treated surface reacts with the compound of interest to form a stable adduct. Numerous samplers can be envisioned which result in reaction or other removal mechanisms for specific compounds or classes of compounds. These are only limited by the cleverness of the investigator.

Sampler Placement

Because of their small size and lack of power needs, passive samplers are relatively easy to place. Essentially, any location can be monitored including community and even personal monitoring. Depending upon the collection medium, some care needs to be taken to ensure that the absorbing medium is not lost due to washout in the rain. For example, secondary enclosures for Palmes samplers supply protection from rain and snow as well as reducing the effects of prevailing wind current on the sampling rates of the samplers. Passive samplers rely on either theoretical or empirical diffusion rates that assume a movement of air across the surface with a relatively narrow range of face velocities (Brown 2000). Too rapid air flow can result in high biases, while too low an air flow has an opposite effect. Diffusion barrier samplers suffer less from this problem than tube type samplers, but all passive samplers have this problem to one degree or another.

Figure 4. Deployment of Passive Samplers in East Boston



The Secondary Enclosures are usually quite simple (See Figure 4.) For Palmes samplers, we use one-quart paint cans. The cans can be painted a neutral color (usually gray) to make them less conspicuous when used in locations subject to foot traffic. Otherwise, they can be left unpainted. The latter is necessary if one is monitoring for VOCs as paint off-gases VOCs for as long as 18 months after application. In community settings, steel paint cans typically last about six months in the outdoor environment if not vandalized or otherwise destroyed. Vandalism and sampler loss through other means is a problem with community-based sampling. Placing of sampler enclosures in unobtrusive locations such as within trees or shrubs, on similarly-colored fences,

and in out-of-the-way locations minimizes this problem. Still, loss of samples must be considered in the design phase of any passive monitoring program.

Limits of Detection

The sampling rates for passive samplers are much lower than for active samplers. While an active sampler might use a pump operating at 4 liters per minute, a passive sampler has an effective sampling rate ranging from about 1 milliliter (mL) per minute to about 50 mL per minute. Thus to obtain an equivalent amount of mass, a passive sampler must operate for about 100 times as long as an active sampler using a pump. Since the mass collected is what determines the overall sensitivity of the sampler, it is this ratio that must guide us in using passive samplers to determine concentrations.

In community settings, passive samplers are typically deployed for durations measured in days or weeks. Palmes samplers, for example, are typically placed for one week. Because of this placement, the samplers give information on one-week average concentrations. This is useful for trends analysis and determination of chronic effects. However, for acute effects, short-term variability, or identification of unusual events, such sampling may not be the optimum choice.

Table 1 presents draft limits of detection (LODs) for the samplers selected for the Logan Air Quality Monitoring Study.

Table 1- Draft limits of detection for passive sampling for air contaminants around Logan International Airport.

Compound	LOD Mass (µg)	LOD Conc (µg/m ³)	LOD Conc (ppb)	Harrison Avenue Mean in 2005 (ppb)	AAL (ppb)	ADL/MDL (Pratt, Bock et al. 2005)	Notes
Benzene	2	5.59	1.75	0.39	0.04	0.04/0.12	Liq Extr'n. GC/FID A
Toluene	2	6.32	1.68	1.23	5.31	0.03/2.00	Liq Extr'n. GC/FID A
Ethylbenzene	2	7.27	1.68	0.16	69.1	0.05/0.09	Liq Extr'n. GC/FID A
Xylene	2	7.27	1.68	0.32	0.06	0.03/0.23	Liq Extr'n. GC/FID A
Formaldehyde	0.1	1.34	1.09	ND	0.27	NA	HPLC Fluorescence
Acetaldehyde	0.1	1.91	1.06	ND	0.28	NA	HPLC Fluorescence
Propionaldehyde	0.1	1.95	0.82	ND	-----	NA	HPLC Fluorescence
Acrolein	0.1	2.47	1.08	ND	-----	NA	HPLC Fluorescence
Napthalene	0.01	0.37	0.07	ND	2.72	NA	Liq Extr'n. GC/FID B

Data assume 7 days = 168 hr sampling. ND means data not reported in The Commonwealth of Massachusetts Air Quality Report 2005

- A. The LODs reported for the BTEX compounds rely on older literature values from our laboratories. We expect a significant improvement in sensitivity with our newer equipment and better reagents. However, if Liquid Extraction cannot be improved to at least the Harrison Avenue means, we will consider thermal desorption, a method improving sensitivity about 100 fold, but increasing cost. At this point, blank variability will dominate the LOD rather than sensitivity of the analytical method. Current literature suggests a limit 0.1 ug may be achievable, which would lower detection limits by a factor of 20.
- B. The published manuscript by Fan, Jung et al. (2006), reports thermal desorption values for high molecular weight PAHs. Naphthalene, as well as the methylated compounds proposed for study, are not stable under thermal desorption and must be Liquid Extracted. We report expected LOD concentrations based on unpublished work by Fan, et al.

- C. Analytical Detection Limit (ADL)) and Method Detection Limit (MDL) are taken from (Pratt, Bock et al. 2005). These values are representative of modern limits of detection for OVM-type VOC samplers. ADL represents the replicate reproducibility. MDL represents the ADL plus a term to account for blank variability.

Methods Validation

The methods chosen for this investigation make use of both active and passive components. Table 2 summarizes the passive sampling and analytical methods for the Logan Air Quality Monitoring Study. Details can be found in **Appendix IV**. The active sampling approaches proposed for this study are EPA-approved or equivalent sample collection methods. The focus of this document, however, is on passive methods. The passive sampling methods suggested are new but offer advantages in cost and portability that will allow a greater number of sites to be monitored. Weaknesses include the need for sampling over longer periods of time precluding gathering information on a short-term basis, e.g., hourly or daily peaks.

Questions have arisen regarding the ability of such passive methods to supply useful information for our investigation. In such settings, passive samplers have many strengths. Most notably, they are small and require no power source; therefore, offering minimal interference in the workplace activities of the wearer. More recently, such samplers have been used extensively in community settings where their portability, low cost, and unobtrusiveness have afforded a much wider distribution of samplers to be made.

Validation of the passive samplers in the context of the Logan Air Quality Monitoring Study will be accomplished in a manner similar to that used to validate passive samplers generally. Numerous papers in the bibliography (**Appendix I**) address this issue. A specific example drawn from our nitrogen dioxide sampling protocol can be found in **Appendix V**. In essence this procedure is accomplished through collocation of active samplers and passive samplers with identical run times. Comparisons are then made between the results obtained by the active and passive samplers, with the active samplers (EPA-approved methods) used as the gold standard. An alternative strategy can be found in our paper on VOC samplers (Cohen, et al., 1990.) Here we created an artificial atmosphere with known concentration and measured the concentration using passive samplers. A comparison with the known and measured results validates the sampling method. We do not propose such a validation method for this study, however.

An excellent paper on cross validation of methods for VOCs has recently appeared (Pratt, Bock et al. 2005). In this work, researchers collocated stainless steel canisters (our selection for active VOC samplers) and OVM badges (our choice for passive VOC samplers in multiple community locations throughout the Minneapolis/St. Paul metropolitan areas. They analyzed the samples collected for a suite of VOCs including BTEX compounds, styrene and other related species. The results were very encouraging and indicate a high degree of association between these two sampling methods. To quote from their discussion:

“OVMs offer cost and deployability advantages over active sampling methods and may be used in situations where active sampling is difficult... or when simultaneous measurements at multiple locations are required. ...”

Prior to the beginning of data collection, we will make similar comparisons in both laboratory and field settings for each of our chosen methods. Part of our protocol development calls for an analysis of such results and a final assessment of the precision, accuracy, and operating conditions for our samplers.

It is most important to note that during the monitoring program itself, passive sampling apparatus will be collocated with active sampling equipment and comparisons made each sampling period. Further, we are proposing placing passive samplers at the Massachusetts Department of Environmental Protection (MDEP) Harrison Avenue site to offer further validation using monitors outside our direct influence. Modifications in sampling strategies or concentration calculations will be adjusted accordingly, if necessary.

Sampling Methods Selected for This Investigation

The methods selected for this investigation are detailed in Appendix I and summarized in **Table 2**. Our research group has extensive experience with the VOC sampler (see Cohen, et al. 1990), and some unpublished results using the Zhang sampler. The Fan-Lioy sampler and the Wagner-Leith sampler are new to our research group.

Table 2 - Logan Air Quality Monitoring Study Passive Sampling and Analytical Methods

Compounds	Samplers/Analytical Protocol	Samplers & Analytical Protocol Description	Validation
VOCs –BTEX & other compounds	Samplers	OVM3500	Cohen, Ryan, et. al, J. Air Waste Mgmt. Assoc., 1990.
	Analytical Protocol	Solvent extraction analysis and gas chromatographic analysis with flame ionization detector.	
Aldehydes and Related Compounds	Samplers	Zhang Sampler	Zhang, J., Environmental Science & Technology, June 2000.
	Analytical Protocol	Solvent extraction of carbonyl compound using gradient high performance liquid chromatography and fluorescence detection.	
PAHs	Samplers	Gas chromatographic column bonded together as an absorption medium.	Fan, Z.H., et al, Environmental Science & Technology, 2000.
	Analytical Protocol	Solvent extraction and gas chromatographic analysis with flame ionization detection.	
PM _{2.5}	Samplers	Wagner-Leith passive aerosol sampler	Wagner, J., and Leith, D., Journal of Aerosol Science, 2001.
	Analytical Protocol	Collection of PM sample on substrate, SEM analysis, modeling of PM concentration using flux measurement and estimated settling velocity	

Literature Cited

- 3M. (2007). "Technical Data Bulletin: Organic Vapor Monitor Sampling and Analysis Guide." from <http://multimedia.mmm.com/mws/mediawebserver.dyn?6666660Zjcf6lVs6EVs666CswCOrrrrQ-> [Accessed 16 February 2007].
- Ayres, M. and P. Ryan (2006). A Longitudinal Study of Nitrogen Dioxide Concentrations around a Major Metropolitan Airport: 1987 – 2005. P. Barry Ryan and Megan M. Ayres. . Joint Annual Meeting of the International Society of Exposure Analysis and International Society for Environmental Epidemiology. Paris, France.
- Brown, R. (2000). "Monitoring the ambient environment with diffusive samplers: theory and practice/." Journal of Environmental Monitoring 2(1): 1-9.
- Brunekreef, B., D. Houthuijs, et al. (1990). "Indoor Nitrogen-Dioxide Exposure and Childrens Pulmonary-Function." Journal of the Air & Waste Management Association 40(9): 1252-1256.
- Cohen, M. A., P. B. Ryan, et al. (1991). "Source Receptor Study of Volatile Organic Compounds and Particulate Matter in the Kanawha Valley, WV .2. Analysis of Factors Contributing to VOC and Particle Exposures." Atmospheric Environment Part B-Urban Atmosphere 25(1): 95-107.
- Cohen, M. A., P. B. Ryan, et al. (1990). "The Validation of a Passive Sampler for Indoor and Outdoor Concentrations of Volatile Organic Compounds." Journal of the Air & Waste Management Association 40(7): 993-997.
- Cohen, M. A., P. B. Ryan, et al. (1989). "Indoor Outdoor Measurements of Volatile Organic-Compounds in the Kanawha Valley of West Virginia." JAPCA 39(8): 1086-1093.
- Draeger. (2007). from http://www.draeger.com/ST/internet/US/en/Products/Detection/Draeger-Tubes/draeger_tubes.jsp [Accessed 16 February 2007].
- Fan, Z., K. Jung, et al. (2006). "Development of a passive sampler to measure personal exposure to gaseous PAHs in community settings. ." Environmental Science & Technology 40(19): 6051-6957.
- Florey, C. D. V., R. J. W. Melia, et al. (1979). "Relation between Respiratory Illness in Primary School Children and the Use of Gas for Cooking .3. Nitrogen Dioxide, Respiratory Illness and Lung Infection." International Journal of Epidemiology 8(4): 347-353.
- Melia, R. J., S. Chinn, et al. (1979). "Relationship between Indoor Air Pollution from Nitrogen Dioxide and Respiratory Illness in Primary School Children." Journal of Epidemiology and Community Health 33(2): 164-164.
- Melia, R. J. W., C. D. Florey, et al. (1982). "Childhood Respiratory Illness and the Home Environment .1. Relations between Nitrogen Dioxide, Temperature and Relative Humidity." International Journal of Epidemiology 11(2): 155-163.
- Melia, R. J. W., C. D. Florey, et al. (1982). "Childhood Respiratory Illness and the Home Environment .2. Association between Respiratory Illness and Nitrogen Dioxide, Temperature and Relative Humidity." International Journal of Epidemiology 11(2): 164-169.
- Melia, R. J. W., C. D. V. Florey, et al. (1980). "Relation between Indoor Air Pollution from Nitrogen Dioxide and Respiratory Illness in Primary School Children." Bulletin Europeen De Physiopathologie Respiratoire-Clinical Respiratory Physiology 16(1): P7-P8.
- Palmes, E. and A. Gunnison (1973). "Personal monitoring device for gaseous contaminants." American Industrial Hygiene Association Journal 34: 78-81.
- Pratt, G., D. Bock, et al. (2005). "A Field Comparison of Volatile Organic Compounds Using Passive Organic Vapor Monitors and Stainless Steel Canisters." Environmental Science & Technology 39(9): 3261-3268.
- Ryan, P. B., M. L. Soczek, et al. (1988). "The Boston Residential NO₂ Characterization Study .1. Preliminary Evaluation of the Survey Methodology." Japca-the International Journal of Air Pollution Control and Hazardous Waste Management 38(1): 22-27.

- Ryan, P. B., M. L. Soczek, et al. (1988). "The Boston Residential NO₂ Characterization Study .2. Survey Methodology and Population Concentration Estimates." Atmospheric Environment 22(10): 2115-2125.
- Ryan, P. B., J. D. Spengler, et al. (1983). "The Effects of Kerosene Heaters on Indoor Pollutant Concentrations - a Monitoring and Modeling Study." Atmospheric Environment 17(7): 1339-1345.
- Spengler, J., M. Schwab, et al. (1994). "Personal Exposure to Nitrogen Dioxide in the Los Angeles Basin." Journal of the Air & Waste Management Association 44(1): 39-47.
- Spengler, J. D., B. G. Ferris, et al. (1979). "Sulfur Dioxide and Nitrogen Dioxide Levels Inside and Outside Homes and the Implications on Health-Effects Research." Environmental Science & Technology 13(10): 1276-1280.
- Zhang, J., L. Zhang, et al. (2000). "Development of the Personal Aldehydes and Ketones Sampler Based Upon DNSH Derivatization on a Solid Sorbent." Environmental Science & Technology 34(12): 2601-2607.

Appendix I - Bibliography on Passive Sampling for Different Pollutants. Compiled by John Watson.

Batterman, S., Hatzvassilis, G., Jia, C.R., 2006. Concentrations and emissions of gasoline and other vapors from residential vehicle garages. *Atmospheric Environment* 40 (10), 1828-1844.

High concentrations of airborne volatile organic compounds (VOCs) may be present in residential garages due to emissions from vehicles, lawnmowers, storage containers, and many other items stored in the garage. VOC emissions will ultimately be transported into ambient air and, if the garage is attached to a residence or other building, into living spaces. This study reports on VOC concentrations and emissions at 15 residential garages in Michigan that varied in type, size, use and other characteristics. VOCs were measured in garages and in outside air using 4-day passive sampling, thermal desorption, and GC-MS analysis. Effective air exchange rates (AERs) were determined using a perfluorocarbon tracer gas and the constant injection method. A modeling analysis shows the effect of time-varying ventilation. To estimate temporal and spatial variability, concentrations were measured on 7 subsequent occasions at multiple locations in one garage. This garage was well-mixed, and the temporal variation in AERs and concentrations was modest. Across the 15 garages, 36 different VOCs in garage air, and 20 in ambient air, were quantified. Source groups identified and attributed to garage emissions included evaporated gasoline, solvents, paints, oils, and cleaners. Concentrations of gasoline-related VOCs in most garages were high, e.g., benzene levels reached $159 \mu\text{g m}^{-3}$ in one garage. TVOC emissions per garage averaged $3.0 \pm 4.1 \text{ g day}^{-1}$, and AERs averaged $0.77 \pm 0.51 \text{ h}^{-1}$. VOC concentrations and AERs were not strongly correlated to observed house, garage or meteorological factors, but appeared largely dependent on occupant activities (opening of the garage door) and VOC sources present. This study quantifies the importance of attached garages as VOC sources, and the results are significant for understanding and mitigating indoor exposures, and for estimating emissions for source inventory purposes. (c) 2005 Elsevier Ltd. All rights reserved

Busbin, D.D., Feigley, C.E., Underhill, D.W., Salzberg, D., 2006. A second look at the Palmes' diffusive sampler. *Journal of the Air & Waste Management Association* 56 (10), 1431-1439.

The Palmes' tube, the first diffusive sampler incorporating a fixed path length, has received wide usage for the sampling of a large number of gaseous pollutants. But despite numerous previous studies, questions remain regarding the accuracy of these inexpensive, simple-to-construct, open-ended samplers. Here the mass transfer resistance in a Palmes' diffusive sampler was measured using the loss of cyclohexane from a Palmes' tube containing liquid cyclohexane at its base. The average loss rates, at factorial combinations of five air incidence angles evenly spaced from 270 degrees to 90 degrees, and five air speeds from 0.5 m/sec to 2.5 m/sec ranged from 46% to 121% higher than rates calculated from the physical dimensions of the sampler, proving the need to calibrate these samplers rather than relying on a theoretical calculation. The mass transfer resistance was nearly constant when the airflow was perpendicular to the sampler and sufficiently high to avoid stagnation, a finding that may explain the widespread acceptance of the results obtained using this sampler

Costabile, F., Bertoni, G., Desantis, F., Wang, F.J., Hong, W.M., Liu, F.L., Allegrini, I., 2006. A preliminary assessment of major air pollutants in the city of Suzhou, China. *Atmospheric Environment* 40 (33), 6380-6395.

Nitrogen oxides (NO₂ and NO_x), sulphur dioxide (SO₂) and benzene, toluene, xylene (BTX) in ambient air were preliminarily assessed, by diffusive sampling technique, in 2003 through three measurement campaigns at 100 locations in the Chinese city of Suzhou. Statistical analysis of space series so-generated was performed to infer source contributions and frequency distributions (FD). It was found that nitrogen oxides, benzene and xylene were mostly emitted from motor vehicles; in contrast, industrial sources were a major contributor to sulfur and toluene pollution. Normal FD (NFD) described significantly SO₂ in summer and NO₂ and NO_x in autumn (95% confidence interval); on the contrary, BTX presented a most peculiar FD rather different to the NFD. Lognormal distribution was often unacceptable. Predominant factors influencing FDs and its normality were found to be associated to those elements conditioning air pollutant diffusion: meteorology (wind speed and direction), relevant emission sources (especially for toluene), emission seasonality (mainly for SO₂ and NO_x), and photochemistry (mainly for NO₂ and xylene). (c) 2006 Elsevier Ltd. All rights reserved

Fan, Z.H., Jung, K.H., Lioy, P.J., 2006. Development of a passive sampler to measure personal exposure to gaseous PAHs in community settings. *Environmental Science & Technology*, 40 (19), 6051-6057.

A sensitive, simple, and cost-effective passive sampling methodology was developed to quantify personal exposure to gaseous polycyclic aromatic hydrocarbons (PAHs). A Fan-Lioy passive PAH sampler (FL-PPS) is constructed from 320 sections of 1-cm long SPB-5 GC columns (0.75-mm i.d. and 7- μm film thickness), similar to a mini-honeycomb denuder. Given the unique feature of the

GC column stationary phase, gaseous PAHs are collected on the inner surfaces of the columns by molecular diffusion and thermally desorbed to GC/MS for analysis. The sampling rates of FL-PPS were determined in the laboratory using a controlled test atmosphere containing eight PAHs for a range of face velocity, temperature, relative humidity, PAH concentration, and sampling duration. The sampling rate (mean, %RSD, cm³/min) was 26.7 (21%) for acenaphthylene, 37.6 (25%) for acenaphthene, 56.2 (13%) for fluorene, 49.1 (25%) for phenanthrene, 62.7 (22%) for anthracene, 65.4 (24%) for fluoranthene, and 64.4 (18%) for pyrene over a sampling duration of 8-48 h. The sampling rate for naphthalene was similar to 14.1 (12%) cm³/min over a sampling period of 8 h but decreased along with an increase of sampling time. The effects of temperature, humidity, face velocity, and PAH concentration on the sampling rate were not significant for all the compounds tested. A reasonable agreement (< 30%) was obtained for most compounds measured by FL-PPS and a conventional active PAH sampling method colocated side-by-side in the field, but a sampling time of 24 h or longer was required for detection of less abundant PAHs in community settings

Fiebig-Wittmaack, M., Schultz, E., Cordova, A.M., Pizarro, C., 2006. A microscopic and chemical study of airborne coarse particles with particular reference to sea salt in Chile at 30 degrees s. *Atmospheric Environment* 40 (19), 3467-3478.

Along a transect ranging from the Pacific to the summit of Cerro Tololo at 2200m above sea level (a.s.l.) in Chile at 30 degrees S, coarse particle concentration was measured at three sites in a one-year study from December 2002 to 2003. The climate of this area is characterised by semi-arid conditions. Intensive thermally induced valley winds occurring particularly in summer, possibly transporting polluted air masses from the coastal area into the mountain region. This may question the background characteristics of Cerro Tololo as suitable site in Chile for a monitoring station of the Global Atmospheric Watch (GAW) program. Particle sampling by a passive sampling technique was employed to analyse composition of particles, find out effective sources and trace possible transport of suspended particles in this area. Temporal resolution of sampling was one week. Composition and size distribution of weekly deposition samples were determined by microscopic single particle analysis and bulk ionchromatographic analysis. Coarse particle concentration decreases differently along the transect as a function of occurring sources and depending on reactivity of components. The percentage of a black particle component remains at the same level of about 4% at all the three sites, confirming biomass burning as a wide-spread pollution. The percentage of sea salt, by contrast, amounts on average about 50% of total coarse particle concentration at the coastal area, quickly decreasing to about 10% along the transect due to losses by particle deposition and chemical reaction during transport. Ammonium shows a different behaviour, characterised by enhanced values at the central part of the transect, due to emissions from agricultural activities in this area. A shift in size distribution between the different sites is explained not only by gravitational fractionation but also by chemical conversion during transport. As a result, it is concluded that an impact of contaminated air at Cerro Tololo cannot be ruled out at a low level particularly in summer. However, the amount, composition and size distribution of the coarse fraction rather confirms the pristine area characteristics of Cerro Tololo and its background conditions. (c) 2006 Elsevier Ltd. All rights reserved

Gevao, B., Al Bahloul, M., Al Ghadban, A.N., Ali, L., Al Omair, A., Helaleh, M., Al Matrouk, K., Zafar, J., 2006. Polybrominated diphenyl ethers in indoor air in Kuwait: Implications for human exposure. *Atmospheric Environment* 40 (8), 1419-1426.

Polyurethane foam plug passive samplers were used to concurrently measure air concentrations of polybrominated diphenyl ethers (PBDEs) in 70 indoor environments. PBDEs were detected in all homes and offices investigated with patterns similar to the distribution in the commercial penta technical formulation (Bromkal 70-5DE). The ubiquitous distribution of these compounds in indoor environments may be due to the volatilization of these chemicals from foam (e.g. mattresses, foam padded furniture), electronic equipments (e.g. TVs, printers, computers) and other consumer products to which they are added as flame retardants. Mean ZPBDEs concentration in air was log-normally distributed and ranged from similar to 2-385pg m⁻³. Using an inhalation rate of 8 and 20m³ day⁻¹ for children and adults respectively, exposure via inhalation is estimated to be 173 and 399pg day⁻¹ for children and adults respectively. This study supports the growing body of evidence for the ubiquitous presence of these compounds in indoor air and the potential for continuous, low-level exposure both at work and home. (c) 2005 Elsevier Ltd. All rights reserved

Harrad, S., Hazrati, S., Ibarra, C., 2006. Concentrations of polychlorinated biphenyls in indoor air and polybrominated diphenyl ethers in indoor air and dust in Birmingham, United Kingdom: Implications for human exposure. *Environmental Science & Technology* 40 (15), 4633-4638.

Polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) were measured in air (using PUF disk passive samplers) in 31 homes, 33 offices, 25 cars, and 3 public microenvironments. Average concentrations of Sigma BDE (273 pg m⁻³) and Sigma PCB (8920 pg m⁻³) were an order of magnitude higher than those previously reported for outdoor air. Cars were the most contaminated microenvironment for Sigma BDE (average = 709 pg m⁻³), but the least for Sigma PCB (average = 1391 pg m⁻³). Comparison with data from a previous spatially consistent study, revealed no significant decline in concentrations of Sigma PCB in

indoor air since 1997-98. Concentrations in indoor dust from 8 homes were on average 215.2 ng Sigma BDE g(-1), slightly higher than other European dust samples, but twenty times lower than Canadian samples. Inhalation makes an important contribution (between 4.2 and 63% for adults) to overall UK exposure to Sigma PCB. For Sigma BDE, dust ingestion makes a significant but in contrast to Canada-a not overwhelming contribution (up to 37% for adults, and 69% for toddlers). Comparison of UK and Canadian estimates of absolute exposure to Sigma BDE suggest that differences in dust contamination are the likely cause of higher Sigma BDE body burdens in North Americans compared to Europeans

Horton, A., Murray, F., Bulsara, M., Hinwood, A., Farrar, D., 2006. Personal monitoring of benzene in Perth, Western Australia: The contribution of sources to non-industrial personal exposure. *Atmospheric Environment*, 40 (14), 2596-2606.

Personal monitoring using passive samplers was conducted in Perth, Western Australia, to determine the concentrations of benzene to which residents were exposed during their daily activities. An additional aim of the study was to assess the contribution of different microenvironments to non-industrial exposure, and the extent to which lifestyle and behaviour influence personal exposure. Fifty participants were recruited and wore passive samplers over 24-h periods for 5 consecutive days (including weekends) in summer (November-March) and winter (June-September). The study commenced in June 2001 and was completed in April 2002. The mean benzene exposure of the participants in summer was 1.76 and 1.98 $\mu\text{g m}^{-3}$ in winter. Statistical analysis using a generalized linear mixed model revealed that refuelling and commuting were the most significant contributors to non-industrial exposure to benzene in summer and winter for Perth residents. (c) 2006 Elsevier Ltd. All rights reserved

Lee, S.J., Demokritou, P., Koutrakis, P., Delgado-Saborit, J.M., 2006. Development and evaluation of personal respirable particulate sampler (PRPS). *Atmospheric Environment* 40 (2), 212-224.

This paper presents the development, laboratory evaluation, and field tests of a personal respirable particulate sampler (PRPS). The PRPS is designed as a personal sampling system to collect particulate matter (PM_{0.5}, PM_{1.0}, PM_{2.5}, PM_{4.5}, and PM₁₀) and gaseous pollutants, including O₃, SO₂, and NO₂. It operates at a flow rate of 5.0 LPM and consists of five selectable impaction stages (with cutpoints of 10, 4.5, 2.5, 1.0, and 0.5 μm), a backup filter, and two diffusion passive samplers. In each impaction stage, particles are collected onto a polyurethane foam (PUF) substrate. This substrate, using no adhesive, was shown to have minimum particle bounce and re-entrainment. A backup 37 mm Teflon membrane filter is used downstream to collect particles smaller than the cutoff diameter of the final impaction stage. The impaction stage cutpoints were characterized in the laboratory using artificially generated polydisperse aerosols. Particle losses for each stage were found to be acceptably low. The performance of the PRPS was also compared with that of a collocated microorifice cascade impactor (MOI) and real-time particle sizing instruments (SMPS/APS) in laboratory experiments using artificially generated particles. The size distributions measured by the PRPS were found to be much closer to those measured by the real-time particle sizing instruments than to those measured by the MOI. A field PM intercomparison study was also conducted using the PRPS and three reference samplers, the Harvard Impactor (HI), the USEPA PM_{2.5} Well Impactor Ninety Six (WINS), and the Harvard Personal Environmental Monitor (Harvard PEM) sampler. The PM₁₀, PM_{2.5}, and sulfate concentrations measured by PRPS were in a very good agreement with those obtained from the reference samplers. (c) 2005 Elsevier Ltd. All rights reserved

Liu, G.Q., Zhang, G., Li, J., Li, X.D., Peng, X.Z., Qi, S.H., 2006. Spatial distribution and seasonal variations of polycyclic aromatic hydrocarbons (PAHs) using semi-permeable membrane devices (SPMD) and pine needles in the Pearl River Delta, South China. *Atmospheric Environment* 40 (17), 3134-3143.

Semi-permeable membrane devices (SPMDs) were deployed at 12 sites in the Pearl River Delta (PRD) during 2001-2002 to elucidate the spatial distribution and seasonal variations of polycyclic aromatic hydrocarbons (PAHs) in the subtropical region. Pine needles from the same sites were also analyzed for PAHs for a comparison with SPMDs. In Guangzhou, high volume active air sampling (HiVol) was carried out weekly through out the year-round sampling campaign. The PAHs sequestered in SPMDs (in ng SPMD⁻¹ day(-1)) were found to be higher in winter than in summer. Using the HiVol data, SPMD sampling rates were calculated seasonally for some dominant gas-phase PAH compounds (Fluorene to Pyrene). These sampling rates ranged from 0.7 to 2.8 m³ day(-1), which were used to determine the atmospheric PAH concentrations at other sites. The calculated PAH concentrations, based on different temperature-dependant SPMD sampling rates, in the air were higher in summer than in winter. The PAH compounds sampled with SPMDs and pine needle were mainly associated with gaseous PAHs, while pine needles accumulated more high molecular weight (HW) PAHs. Good agreements were found in the spatial distribution of atmospheric PAHs measured by SPMDs and pine needles. The potential of using SPMDs for seasonal monitoring of atmospheric organic pollutants at a regional scale was demonstrated. (c) 2006 Published by Elsevier Ltd

Piechocki-Minguy, A., Plaisance, H., Schadkowski, C., Sagnier, I., Saison, J.Y., Galloo, J.C., Guillermo, R., 2006. A case study of personal exposure to nitrogen dioxide using a new high sensitive diffusive sampler. *Science of the Total Environment* 366 (1), 55-64.

Personal NO₂ exposure measurements were achieved during two campaigns in a large northern France city. These campaigns were following an innovating approach based on sequential exposure measurements by diffusive samplers distinguishing four categories of microenvironments ("home", "other indoor places", "transport" and "outdoors"). The objective of these campaigns was to obtain NO₂ personal exposure data in different microenvironments and to examine the determinants of personal exposure to this pollutant. Each campaign comprised two 24-h sampling periods: one during a working day and the second during the weekend. The average total NO₂ personal exposure ranged from 17 $\mu\text{g m}^{-3}$ for the summer weekend samplings to 38 $\mu\text{g m}^{-3}$ for the winter weekday samplings. The highest levels were found in transports and outdoors, the intermediate ones in other indoor places and the lowest in homes. Despite their weak levels, indoor environments contributed for more than 78% to total NO₂ personal exposure because of more time spent in these living places. A Multiple Correspondence Analysis (MCA) highlighted the determinants of NO₂ personal exposure in the "home" and "transport" microenvironments. This led to a classification of NO₂ personal exposure levels according to different means of transport: from the lowest to the highest exposure levels, train, tramway or underground, bicycle, car or motorcycle. In homes, the rise of NO₂ personal exposures is mainly due to the use of gas stoves and gas heating and the absence of automatic airing system. A classification of NO₂ personal exposure levels was set up according to the characteristics of homes. An analysis of correlations between the home NO₂ personal exposures and outdoor concentrations measured by fixed ambient air monitoring stations showed weak relations suggesting that the data of these stations are poor predictors of NO₂ personal exposures in homes. (c) 2005 Elsevier B.V. All rights reserved

Smith, L., Mukerjee, S., Gonzales, M., Stallings, C., Neas, L., Norris, G., Ozkaynak, H., 2006. Use of GIS and ancillary variables compound and nitrogen dioxide to predict volatile organic levels at unmonitored locations. *Atmospheric Environment* 40 (20), 3773-3787.

In late 1999, passive air sampling of nitrogen dioxide (NO₂) and volatile organic compounds was conducted at 22 school locations and two intensive sites in El Paso, Texas. Our goal was to predict concentrations of NO₂ and benzene, toluene, ethylbenzene, o-xylene, and m,p-xylene at a total of 55 schools. The predictive equations were developed by regressing the passive monitor measurements at the 22 monitored schools on land-use variables derived from a geographic information system (GIS). These GIS-based ancillary variables included distance to the nearest border crossing, elevation, population density, distance to roads with specified traffic volumes, traffic intensity around the schools, and distance to the nearest petroleum facility. The reliability of the predictive equations was assessed at the two intensive monitoring sites. For all pollutants, the most useful predictive ancillary variables were elevation, population density, distance to a border crossing, and distance to a petroleum facility. For estimating NO₂, traffic intensity was also important. (c) 2006 Elsevier Ltd. All rights reserved

Thammakhet, C., Muneesawang, V., Thavarungkul, P., Kanatharana, P., 2006. Cost effective passive sampling device for volatile organic compounds monitoring. *Atmospheric Environment*, 40 (24), 4589-4596.

A laboratory-built passive sampler was developed as a simple and cost effective device for monitoring volatile organic compounds (VOCs) such as benzene, toluene and xylene (BTX). Common glass bottles (screw cap, 10 ml, 67.6 x 10.6 mm ID), packed with 75 mg of activated Tenax TA, were used as passive samplers. After exposed to real sample, the adsorbent was desorbed using a laboratory-built thermal desorption device. The analytes were purged to fill a sampling loop and then injected by a gas sampling valve to a gas chromatograph with a flame ionization detector (FID). All parameters, i.e., desorption time, purge flow rate, gas chromatograph conditions were optimized to obtain high sensitivity, resolution and short analysis time. The system was calibrated by BTX standard gas and the linear regression coefficient of greater than 0.99 was obtained with detection limits 0.3, 0.2 and 0.7 $\mu\text{g m}^{-3}$ for benzene, toluene and xylene, respectively. The proposed method was implemented for the monitoring of BTX at 10 gasoline stations in Hat Yai, Thailand. The concentrations were found in the range of N.D.-19, 12-200 and 23-200 $\mu\text{g m}^{-3}$ for benzene, toluene and xylene, respectively. (c) 2006 Elsevier Ltd. All rights reserved

Willers, S.M., Brunekreef, B., Oldenwening, M., Smit, H.A., Kerkhof, M., De Vries, H., 2006. Gas cooking, kitchen ventilation, and exposure to combustion products. *Indoor Air* 16 (1), 65-73.

We evaluated a questionnaire-based system for classifying homes into groups with distinctly different chances of accumulating combustion products from cooking appliances. The system was based on questions about type of cooking appliance, type and use of ventilation provisions, and kitchen size. Real-time measurements were made of CO, CO₂, temperature, and water vapor, and passive sampling was performed of nitrogen oxides, over a week-long period in 74 kitchens. During the measurements, inhabitants kept a diary to record appliance use time and use of ventilation provisions. The questionnaire-based and diary-based home classifications for

the 'Chance of Accumulation of Combustion Products' (CACP) turned out to agree fairly well. For CO₂ as well as for CO a significant difference between the 'high' and 'low' CACP groups was found for the mean accumulation in the kitchen during cooking of the combustion generated concentrations. These facts are considered to be important experimental evidence of the CACP stratification being valid for our study population. In the homes studied, NO₂ as well as CO concentrations were found to be lower compared with previous studies in The Netherlands

Zhao, Y., Wang, Q., Satake, K., Tsunoda, K.I., 2006. Alternative normalization method of atmospheric polycyclic aromatic hydrocarbons pollution level recorded by tree bark. *Environmental Science & Technology* 40 (19), 5853-5859.

An alternative normalization method was developed for evaluating atmospheric polycyclic aromatic hydrocarbons (PAHs) pollution level when using tree bark as a passive sampling medium. Perylene (PER), which mainly stems from natural biogenic processes, was proposed as a "natural internal compound" (NIC) of atmospheric PAHs accumulation processes from air into the bark, and a concentration ratio of target PAH to PER (R-PAH/PER) was used to minimize the uncertainty in the evaluation of atmospheric PAHs pollution level. Systematic investigation of the effects of intrinsic bark characteristics and extrinsic seasonal meteorological conditions on the partition processes of atmospheric PAHs indicated that R-PAH/PER is as an alternative index as compared to bark mass concentration (BMCPAH, ng/g dry bark), lipid mass concentration (LMCPAH, ng/g lipid of bark), and area mass concentration (AMC(PAH), ng/m² surface area of bark) for the evaluation of atmospheric PAHs pollution and that it allows more flexible sampling of tree barks. Clearly, the methodology should be expected to be useful for the objective evaluation of atmospheric pollution levels of other persistent organic pollutants when using tree bark and other passive sampling media if corresponding NICs are found in the future

Alonso, R., Bytnerowicz, A., Boarman, W.I., 2005. Atmospheric dry deposition in the vicinity of the Salton Sea, California - I: Air pollution and deposition in a desert environment. *Atmospheric Environment* 39 (26), 4671-4679.

Air pollutant concentrations and atmospheric dry deposition were monitored seasonally at the Salton Sea, southern California. Measurements of ozone (O₃), nitric acid vapor (HNO₃), ammonia (NH₃), nitric oxide (NO), nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) were performed using passive samplers. Deposition rates of NO₃⁻, NH₄⁺, Cl⁻, SO₄²⁻, Na⁺, K⁺ and Ca²⁺ to creosote bush branches and nylon filters as surrogate surfaces were determined for oneweek long exposure periods. Maximum O₃ values were recorded in spring with 24-h average values of 108.8 μg m⁻³. Concentrations of NO and NO₂ were low and within ranges of the non-urban areas in California (0.4-5.6 and 3.3-16.2 μg m⁻³ ranges, respectively). Concentrations of HNO₃ (2.0-6.7 μg m⁻³) and NH₃ (6.4-15.7 μg m⁻³) were elevated and above the levels typical for remote locations in California. Deposition rates of Cl⁻, SO₄²⁻, Na⁺, K⁺ and Ca²⁺ were related to the influence of sea spray or to suspended soil particles, and no strong enrichments caused by ions originated by human activities were detected. Dry deposition rates of NO₃⁻ and NH₄⁺ were similar to values registered in areas where symptoms of nitrogen saturation and changes in species composition have been described. Deposition of nitrogenous compounds might be contributing to eutrophication processes at the Salton Sea. (c) 2005 Elsevier Ltd. All rights reserved

Bruno, P., Caputi, M., Caselli, M., de Gennaro, G., de Rienzo, M., 2005. Reliability of a BTEX radial diffusive sampler for thermal desorption: Field measurements. *Atmospheric Environment* 39 (7), 1347-1355.

Radiello(R), a radial symmetry diffusive sampler, has been evaluated for its potential for ambient air quality monitoring, in particular for benzene, toluene, ethyl benzene, p-xylene, m-xylene, o-xylene (BTEX) measurements. BTEX were first sampled onto adsorbing cartridges before analyses were performed by thermal desorption and GC-MS. Tests were carried out to determine blank values and any storage effects. The results of an investigation into repeatability of the Radiello(R) sampler and the influence of sampling time under field conditions are reported. Inter-comparison with automatic instruments is also illustrated. (C) 2004 Elsevier Ltd. All rights reserved

Bytnerowicz, A., Sanz, M.J., Arbaugh, M.J., Padgett, P.E., Jones, D.P., Davila, A., 2005. Passive sampler for monitoring ambient nitric acid (HNO₃) and nitrous acid (HNO₂) concentrations. *Atmospheric Environment* 39 (14), 2655-2660.

A passive sampler for collection of gaseous nitric acid (HNO₃) and nitrous acid (HNO₂) is based on a diffusion of ambient air through Teflon membrane and absorption of the pollutants on Nylasorb nylon filter. The sampler is simple in design, easy to make, inexpensive and resistant to harsh weather conditions. The sampler has been calibrated against honeycomb denuder systems in ambient southern California air and in controlled HNO₃ exposures. It is more precise than the old open-face HNO₃ sampler. It can measure wide ranges of ambient HNO₂ and HNO₃ concentrations for extended periods of time and can be used for regional-scale monitoring of the pollutants. Published by Elsevier Ltd

Chatzis, C., Alexopoulos, E.C., Linos, A., 2005. Indoor and outdoor personal exposure to benzene in Athens, Greece. *Science of the Total Environment* 349 (1-3), 72-80.

Objective: To evaluate the exposure of urban inhabitants to atmospheric benzene in Athens, Greece. Methods: Fifty non-smoker volunteers from selected occupational groups and their homes were monitored by passive air samplers for six 5-day periods during a year. An activity diary was completed during each sampling period and relevant data were collected by a questionnaire at the beginning of the study. Additional data on urban levels on benzene were also available. Results: Average benzene home and personal levels in six monitoring campaigns varied between 6.0-13.4 and 13.1-24.6 $\mu\text{g}/\text{m}^3$, respectively. Urban levels varied between 15.4 and 27.9 $\mu\text{g}/\text{m}^3$ with an annual mean of 20.4 $\mu\text{g}/\text{m}^3$. Wind speed seems to determine largely home levels and personal exposure. Proximity to busy road holds also an important influence on indoor benzene levels. Adjusted for seasonal or climate variation, other significant prognostic factors of personal exposure were home levels, total time spent outdoors and transportation mean. Time spent outdoors explains the strong relationship between occupation and personal levels of exposure. Wind had similar effect in clearing indoor and urban pollution in Athens; lessen personal exposure and home levels about 2-2.5 $\mu\text{g}/\text{m}^3$ per 1 m/s increase in speed. Conclusions: Factors related to climate (use of non-absorbent materials for wall and floor covering and frequent ventilation) might be one explanation for homes' high clearing rate. Our exposure pattern, which suggests that outdoors work give the greater contribution to benzene exposure of Athens citizens, is uncommon in northern towns of Europe. Policy makers have to take in account these differences in establishing guidelines for ambient benzene exposure. (c) 2005 Elsevier B.V. All rights reserved

EN 13528-1, 2005. Ambient air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Requirements and test methods Part 1: General requirements.

Farrar, N.J., Harner, T.J., Sweetman, A.J., Jones, K.C., 2005. Field calibration of rapidly equilibrating thin-film passive air samplers and their potential application for low-volume air sampling studies. *Environmental Science & Technology* 39 (1), 261-267.

This paper reports on a field calibration and ambient deployment study with rapidly equilibrating thin-film passive air samplers. POLYmer-coated Glass (POG) samplers have a coating of ethylene vinyl acetate (EVA) less than 1 μm thick coated on to glass, which can be dissolved off after exposure and prepared for quantification of persistent organic pollutants (POPs) that have partitioned into the film during field exposure. In this study, POGs were exposed for up to 18 d, in a study to assess compound uptake rates and their time to approach equilibrium. Results confirmed theoretical predictions, with time to equilibrium varying between a few hours to ca. 20 d for PCB-18 and PCB-138, respectively. Performance reference compounds and contaminated POGs were used to investigate depuration kinetics, confirming that lighter congeners behave extremely dynamically with substantial losses from the films over periods of a few hours. Repeated deployments of the samplers for different 3-d periods yielded detectable levels of a range of PCB congeners, which had partitioned from as little as similar to 2 to 10 m^3 air. This highlights the potential utility of POGs for extremely sensitive and dynamic passive air sampling in the future to help improve understanding of sources, environmental fate, and behavior of POPs. Recommendations are made for future improvements/refinements in POG sampling and handling procedures

Farrar, N.J., Harner, T., Shoeib, M., Sweetman, A., Jones, K.C., 2005. Field deployment of thin film passive air samplers for persistent organic pollutants: A study in the urban atmospheric boundary layer. *Environmental Science & Technology* 39 (1), 42-48.

This paper reports on the first field deployment of rapidly equilibrating thin-film passive air samplers under ambient conditions. The Polymer-coated Glass (POG) samplers have a coating of ethylene vinyl acetate (EVA) less than 1 μm thick applied to a glass surface. This can be dissolved off after exposure and prepared for the quantification of persistent organic pollutants (POPs) that have partitioned into the film during field exposure. In this study, POGs were deployed at various heights on the CN Tower in Toronto, Canada, to investigate the vertical distribution of selected compounds (PCBs, PAHs, organochlorine pesticides) in the atmospheric boundary layer of an urban area. The feasibility of the method to detect POPs from a few cubic meters of air was demonstrated, indicating the potential for rapid, low-volume sampling of air for ambient levels of POPs. PAH levels declined sharply with height, confirming ground-level emissions in urban areas as sources of these compounds; PCBs did the same, although less strongly. Different sampling events detected different vertical distributions of OC pesticides which could be related to local or distant sources, and variations in POPs on the samplers in these different events/heights demonstrate the dynamic nature of sources and atmospheric mixing of POPs

Gerboles, M., Buzica, D., Amantini, L., 2005. Modification of the Palmes diffusion tube and semi-empirical modelling of the uptake rate for monitoring nitrogen dioxide. *Atmospheric Environment* 39 (14), 2579-2592.

Hereafter, a modification of the traditional Palmes diffusion tube by fitting a membrane at the open end of the tube is presented. The membrane is placed to avoid the effect of turbulence due to wind speed. Further optimisations of the volume of absorbent and number of meshes retaining the absorbent are also described. Finally, the sampler is placed in an air proof container and is ready to use in order to improve the quality of measurement. In order to evaluate the performance of the membrane-closed Palmes diffusion tube to monitor nitrogen dioxide (NO₂), experiments were carried out in an exposure chamber. The relative effect of NO₂, temperature, humidity, averaging time and wind speed on the uptake rate of the sampler were then studied. Among the uncontrolled variables, temperature and humidity are found to be the most important ones leading to variability of the uptake rate. Two equations, used to estimate the uptake rate are established. These equations were then applied on some field data and laboratory inter-comparison tests. The agreement between the chemiluminescence method and diffusive samplers changes from 20% of mean bias with the traditional Palmes diffusion tubes to 5% of mean bias with the membrane-closed Palmes tube (MCPT) at the same monitoring site. In the laboratory inter-comparison, the MCPT has shown to be able to correctly measure NO₂ under two extreme exposure conditions in contrast with other diffusive samplers. The uncertainty of the sampler is evaluated. It fulfils the European Directive data quality objective of 25% for accuracy and therefore the sampler qualifies as an indicative method for NO₂ monitoring. (c) 2005 Elsevier Ltd. All rights reserved

Gonzalez-Flesca, N., Frezier, A., 2005. A new laboratory test chamber for the determination of diffusive sampler uptake rates. *Atmospheric Environment* 39 (22), 4049-4056.

Diffusive samplers are today widely used for air quality control in indoor and outdoor environments and for personal exposure studies as well. The uptake rate is a fundamental parameter of a sampler for the calculation of the concentration of the substance to be monitored depends directly on it. Uptake rates can be affected by numerous factors. Their values and the range of validity have to be determined in an appropriate exposure chamber. The laboratory test chamber presented here consists of a loop made of glass, stainless steel and PTFE containing the generated atmosphere in which diffusive samplers can be tested. It is possible to accommodate several samplers simultaneously and simulate various environmental conditions such as temperature, wind speed, wind direction, humidity, atmospheric composition, total pressure and exposure duration. All working parameters have to be monitored including the concentrations of the components of the generated atmosphere. It is shown that the expected concentration of a volatile compound like benzene can be reached very quickly whereas those of less volatile compounds like toluene or xylenes takes longer. The procedure for overcoming this difficulty is described in this paper. By means of an application it is also shown that exposure duration can unequally affect diffusive sampler uptake rates depending on sampler geometry and the nature of the adsorbent. It appears that a radial high-uptake rate diffusive sampler packed with a thermally desorbable material may be unsuitable for long-term monitoring of a volatile compound like benzene. However an axial low-uptake rate diffusive sampler, also packed with a thermally desorbable material, seems more appropriate for this application due to the higher stability of its uptake rate. (c) 2005 Elsevier Ltd. All rights reserved

Gouin, T., Harner, T., Daly, G.L., Wania, F., Mackay, D., Jones, K.C., 2005. Variability of concentrations of polybrominated diphenyl ethers and polychlorinated biphenyls in air: implications for monitoring, modeling and control. *Atmospheric Environment* 39 (1), 151-166.

Monitoring data indicate that organic compounds with high octanol-air partition coefficients (K_{OA}), such as polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) exhibit seasonally variable air concentrations, especially during early spring, shortly after snow melt and before bud-burst when levels are elevated. This variability can complicate the interpretation of monitoring data designed to assess year-to-year changes. It is suggested that relatively simple dynamic multimedia mass balance models can assist interpretation by out variability attributable to temperature and other seasonal effects as well as identifying likely contaminant sources. To illustrate this approach, high-volume air samples were collected from January to June, 2002 at a rural location in southern Ontario. Gas-phase concentrations for both SigmaPBDE and SigmaPCB rose from below the detection limit during the winter to 19 and 110 pg m⁻³, respectively, in early spring, only to decrease again following bud-burst. Passive air samples (PAS), deployed at seven urban, rural and remote sites for two one-month periods prior and following bud-burst, indicate a strong urban-rural gradient for both the PBDEs and PCBs. Calculated air concentrations from the PAS are shown to agree favorably with the high-volume air sampling data, with concentrations ranging 6-85 pg m⁻³ and 6-360 pg m⁻³ for SigmaPBDE and SigmaPCB, respectively. Concentrations in urban areas are typically 5 times greater than in rural locations. These data were interpreted using simulation results from a fate model including a seasonally variable forest canopy and snow pack, suggesting that the primary source is urban and that the "spring pulse" is the result of several interacting factors. Such contaminants are believed to be efficiently deposited in winter, accumulate in the snow pack and are released to terrestrial surfaces upon snow melt in spring. Warmer temperatures cause volatilization and a rise in air concentrations until uptake in emerging foliage leads to a decline in late spring. Implications for monitoring are discussed. (C) 2004 Elsevier Ltd. All rights reserved

Gouin, T., Harner, T., Blanchard, P., Mackay, D., 2005. Passive and active air samplers as complementary methods for investigating persistent organic pollutants in the Great Lakes basin. *Environmental Science & Technology* 39 (23), 9115-9122.

Data obtained using passive air samplers (PAS) are compared to active high-volume air sampling data in order to assess the feasibility of the PAS as a method, complementary to active high-volume air sampling (AAS), for monitoring levels of organochlorine (OC) pesticides, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) in the Laurentian Great Lakes. PAS were deployed at 15 of the Integrated Atmospheric Deposition Network (IADN) sites on a quarterly basis between July 2002 and June 2003, and PAS and AAS results are compared. Levels for the OC pesticides are typically highest in agricultural areas, with endosulfan I dominating air concentrations with values ranging between 40 and 1090 pg(.)m(-3), dieldrin values between 15 and 165 pg(.)m(-3), and gamma-HCH values between 13 and 100 pg(.)m(-3). alpha-HCH was seen to be relatively uniform across the Great Lakes Basin with values ranging between 15 and 73 pg(.)m(-3). Large urban centers, such as Chicago and Toronto, have the highest levels of PCBs and PBDEs that range between 400 and 1200 pg(.)m(-3) and 10 and 70 pg(.)m(-3), respectively. Comparison of the AAS and the PAS data collected during this study shows good agreement, within a factor of 2 or 3, suggesting that the two sample methods produce comparable results. It is suggested that PAS networks, while providing data that are different in nature from AAS, can provide a cost-effective and complementary approach for monitoring the spatial and temporal trends of persistent organic pollutants

Isobe, Y., Yamada, K., Wang, Q.Y., Sakamoto, K., Uchiyama, I., Mizoguchi, T., Zhou, Y.R., 2005. Measurement of indoor sulfur dioxide emission from coal-biomass briquettes. *Water Air and Soil Pollution* 163 (1-4), 341-353.

The coal-biomass briquette is an alternative fuel that replaces low-grade coal. It is expected that the use of coal-biomass briquettes will effectively reduce the indoor concentration of sulfur dioxide (SO₂) emitted during raw coal combustion. In this study, indoor concentrations of SO₂ emitted from combustion of either coal-biomass briquettes or low-grade coal in households in Nanchuan, which is in the rural area of Chongqing City, China, were measured. The acidic gases were collected using passive samplers, and the samplers were taken to the laboratory for extraction and measurement. The SO₂ concentrations resulting from the use of coal-biomass briquettes were clearly reduced compared with those resulting from the use of low-grade coal. The concentrations of SO₂ to which the inhabitants (housewives) of the houses were exposed were also measured, and were found to be less with coal-biomass briquettes. Although with coal-biomass briquettes exposure concentrations still exceeded the World Health Organization guideline for SO₂ (125 µg m(-3)), indoor air pollution and adverse effects on human health caused by SO₂ could be decreased by substituting coal-biomass briquettes for low-grade coal as a domestic fuel

Jaward, T.M., Zhang, G., Nam, J.J., Sweetman, A.J., Obbard, J.P., Kobara, Y., Jones, K.C., 2005. Passive air sampling of polychlorinated biphenyls, organochlorine compounds, and polybrominated diphenyl ethers across Asia. *Environmental Science & Technology* 39 (22), 8638-8645.

Asia is of global importance economically, yet data on ambient persistent organic pollutant levels are still sparse for the region, despite international efforts under the Stockholm Convention to identify and reduce emissions. A large-scale passive air sampling survey was therefore conducted in Asia, specifically in China, Japan, South Korea, and Singapore. Polyurethane foam disks were deployed simultaneously at 77 sites, between Sept 21 and Nov 16, 2004, and analyzed for polychlorinated biphenyls (PCBs), organochlorine compounds (hexachlorobenzene (HCB), dichlorodiphenyltrichloroethanes (DDTs), chlordane), and polybrominated diphenyl ethers (PBDEs). The meteorological conditions prevailing in the region at this time facilitated the assessment of local/regional differences in atmospheric emissions, because large-scale advection effects due to monsoons or dust storms did not occur. Air concentrations estimated assuming an average sampler uptake rate of 3.5 m(3)/day ranged as follows (pg m(-3)): PCBs, 5-340; HCB, 10-460; DDTs, 0.4-1800; chlordanes, 1-660; PBDEs, <0.13-340. South Korea and Singapore generally had regionally low concentrations. Elevated concentrations of PCBs, DDTs and HCB occurred at sites in China, higher than reported in a similar recent sampling campaign in Europe. Chlordane was highest in samples from Japan (which also had elevated levels of PCBs and DDTs) and was also elevated in some Chinese locations. PBDE levels were generally low in the region

Kirchner, M., Jakobi, G., Felcht, E., Bernhardt, M., Fischer, A., 2005. Elevated NH₃ and NO₂ air concentrations and nitrogen deposition rates in the vicinity of a highway in Southern Bavaria. *Atmospheric Environment* 39 (25), 4531-4542.

A transect study consisting of air concentration and deposition measurements of nitrogen compounds was performed to estimate the potential influence of car emissions on the nitrogen input to ecosystems. Therefore, two transects each consisting of 4 plots, the first in a coniferous forest and the second one in an extensively farmed grassland, were installed perpendicular to a highway south of Munich (Bavaria). Both profiles were influenced mainly by car emissions and showed only small local influences caused by agricultural activities. In the framework of a pilot study based upon denuder measurements we found a strong temporal dependency of both nitrogen dioxide (NO₂) and ammonia (NH₃) concentrations on traffic density. In the main study air concentrations of NO₂ and NH₃

were measured by passive samplers; they used as the basis for the estimation of dry deposition. These estimations have been compared with the results of analyses from simultaneously conducted canopy throughfall deposition and open air bulk measurements of nitrate (NO_3^-) and ammonium (NH_4^+). Additionally, within the forest transect the variety of different soil vegetation species was recorded and quantified. We obtained a strong gradient of gas concentrations along both profiles. Whereas the bulk deposition remained quite constant along the non-forested transect, the nitrogen throughfall deposition rate diminished substantially with the distance from the highway. The deposition rate at the forest edge was twice of that inside. The nitrogen load estimated for the examined forest in the vicinity of the highway was comparable to other forest ecosystems situated near diffuse emission sources from agriculture. It could be shown that changes in soil composition and soil vegetation along the forest transect are caused by decreasing nitrogen deposition with distance from the highway. The application of road salt in winter leads to further impacts. (c) 2005 Published by Elsevier Ltd

Martin, N.A., Duckworth, P., Henderson, M.H., Swann, N.R.W., Granshaw, S.T., Lipscombe, R.P., Goody, B.A., 2005. Measurements of environmental 1,3-butadiene with pumped and diffusive samplers using the sorbent Carbo-pack X. Atmospheric Environment 39 (6), 1069-1077.

Studies with the sorbent Carbo-pack X in pumped and diffusive samplers, of the Perkin-Elmer-type, have been carried out using a controlled atmosphere test facility (CATFAC) to generate 1,3-butadiene, together with benzene, at environmental levels. The 7-day and 14-day 1,3-butadiene diffusive uptake rates for this sorbent have been determined to be respectively $(1.24 \pm 0.16) \text{ ng ppm}^{-1} \text{ min}^{-1}$ $((0.55 \pm 0.07) \text{ cm}^3 \text{ min}^{-1})$ and $(1.02 \pm 0.12) \text{ ng ppm}^{-1} \text{ min}^{-1}$ $((0.45 \pm 0.05) \text{ cm}^3 \text{ min}^{-1})$ under a wide range of concentrations at 20°C, 50% relative humidity and a wind speed of 1 m s^{-1} . Preliminary studies indicate that this sorbent may also be useful in radial diffusive samplers for short-term monitoring over a few hours. A pumped sampling method has been developed to measure both 1,3-butadiene and benzene simultaneously over a period of 14-days using two Perkin-Elmer-type devices coupled to an in-house developed controlled flow air sampler. The 1,3-butadiene safe sampling volume for Carbo-pack X has been measured yielding a value of less than or equal to 82 litre g^{-1} . Tests carried out with calibrated amounts of 1,3-butadiene (50 ng and 150 ng) on Carbo-pack X indicate that samplers should be stored in a refrigerator prior to thermal desorption in order to achieve a recovery of effectively 100%. Ambient ozone does not appear to react with 1,3-butadiene adsorbed in the samplers. (C) 2004 Elsevier Ltd. All rights reserved

Paschke, H., Popp, P., 2005. New passive samplers for chlorinated semivolatile organic pollutants in ambient air. Chemosphere 58 (7), 855-863.

Two new types of passive samplers were designed and tested on semivolatile organic compounds. The first type (a spiral-rod sampler) consists of a low-density polyethylene membrane acting as a permeation film and a silicone elastomer as the receiving material; the second (a stir-bar sampler) has the same membrane material but a polydimethylsiloxane-coated stir bar acting as the collector phase and installed radially symmetrically in the sampler. The advantages of the new samplers are their simple design, low costs, and their easy processing via thermodesorption coupled with capillary gas chromatography and mass selective detection. In both samplers, the uptake of selected analytes was integrative over exposure periods of up to 384h. The sampling rates calculated from a laboratory calibration study using the chlorinated semivolatiles hexachlorobenzene, hexachlorocyclohexane isomers and polychlorinated biphenyls ranged from 88.1 ml h^{-1} for δ -hexachlorocyclohexane to 3443 ml h^{-1} for 2,2',5,5'-tetrachlorobiphenyl. A field trial at a hazardous waste dump near Bitterfeld, Germany, for up to 21 days combined with periodical determinations of air concentrations using low-volume sampling indicated that the new samplers can in principle be used in the field, although the sampling rates derived from the field results differed considerably from the laboratory findings. Nevertheless the preliminary results suggest that the new sampler types are promising for the long-term air monitoring of semivolatiles. (C) 2004 Elsevier Ltd. All rights reserved

Pehnec, G., Vadjic, V., Hrsak, J., 2005. Measurements of ozone concentrations in Zagreb. Environmental Monitoring and Assessment 105 (1-3), 165-174.

Ozone concentrations were measured in Zagreb at four sites from May 1999 to April 2001 in order to categorize the air quality with respect to ozone. In the summer of 2000, the ozone measurements were also extended to four sites in the suburbs of Zagreb. Methods of active and passive sampling with nitrite ion as a reagent were used. In the northern part of the town ozone was analyzed by an automatic device. Automatic device measurements in the years 1999 and 2000 showed that hourly averages of ozone concentrations did not exceed the Croatian recommended value of the 98th percentile ($180 \mu\text{g m}^{-3}$). Over the two-year period, 24-h averages occasionally exceed $110 \mu\text{g m}^{-3}$ in city center and in the northern part of the town. Regardless of these isolated examples, ozone was well within acceptable concentrations. Ozone concentrations measured in summer 2000 were higher in the suburbs of Zagreb than in the city. The 98th percentile values higher than $110 \mu\text{g m}^{-3}$ were recorded at three sites

Pennequin-Cardinal, A., Plaisance, H., Locoge, N., Ramalho, O., Kirchner, S., Galloo, J.C., 2005. Performances of the Radiello(R) diffusive sampler for BTEX measurements: Influence of environmental conditions and determination of modelled sampling rates. *Atmospheric Environment* 39 (14), 2535-2544.

Radiello (R) diffusive samplers filled with a thermally desorbable adsorbent (graphitised carbon Carbograph 4) have been evaluated for the monitoring of BTEX according to the European standard EN 13528-2. Blank values and analytical recovery rates were in agreement with the requirements of this protocol. The sampling rates have been estimated under various controlled atmospheres in order to evaluate the effects of some environmental factors on the performances of the Radiello (R) sampler: concentration levels, temperature, exposure time, humidity and wind velocity. The effects of back diffusion and a mixture of 37 VOC have been determined. According to the whole of these results, modelled sampling rates have been set up. These experiments in exposure chamber showed that, for a medium level of concentration in air (5 $\mu\text{g m}^{-3}$) for benzene, the expanded uncertainties were between 20% for benzene and 27% for m/p-xylene under environmental indoor conditions and between 19% for benzene and 31% for m/p-xylene under environmental outdoor conditions. The result for benzene is conform to the requirements of the future European 3 Directive for benzene which define the maximum of uncertainty to 25% for annual concentrations near 5 $\mu\text{g m}^{-3}$). (c) 2005 Elsevier Ltd. All rights reserved

Pilidis, G.A., Karakitsios, S.P., Kassomenos, P.A., 2005. BTX measurements in a medium-sized European city. *Atmospheric Environment* 39 (33), 6051-6065.

The BTX levels are significantly high compared to the EU directive for benzene in European cities with population around or higher one million. Since there are hundreds of towns in Europe with smaller population, it is important to know the levels of aromatics in these areas. This work presents the results of a benzene, toluene and xylene (BTX) measurement campaign that took place in Ioannina, a medium-sized Greek city. As a result of traffic situation and the local meteorological conditions, pollution levels in Ioannina are unusually high, at least for a city of that size. BTX levels were measured using passive samplers placed at several points around the city, as well as across a selected street canyon using both passive and active samplers, combined with simultaneous measurements of traffic flow and wind speed. The measurement procedure was repeated in an exact manner for all four seasons and the results suggest that benzene levels, at all sampling points, exceed the limit set by EU Directive 2000/69. Benzene levels appear correlated to traffic density, while benzene/toluene/xylene ratios present a seasonal variation linked to meteorological conditions. (c) 2005 Elsevier Ltd. All rights reserved

Pratt, G.C., Bock, D., Stock, T.H., Morandi, M., Adgate, J.L., Ramachandran, G., Mongin, S.J., Sexton, K., 2005. A field comparison of volatile organic compound measurements using passive organic vapor monitors and stainless steel canisters. *Environmental Science & Technology* 39 (9), 3261-3268 .

Concurrent field measurements of 10 volatile organic compounds (VOCs) were made using passive diffusion-based organic vapor monitors (OVMs) and the U.S. Federal Reference Method, which comprises active monitoring with stainless steel canisters (CANs). Measurements were obtained throughout a range of weather conditions, repeatedly over the course of three seasons, and at three different locations in the Minneapolis/St. Paul metropolitan area. Ambient concentrations of most VOCs as measured by both methods were low compared to those of other large metropolitan areas. For some VOCs a considerable fraction of measurements was below the detection limit of one or both methods. The observed differences between the two methods were similar across measurement sites, seasons, and meteorological variables. A Bayesian analysis with uniform priors on the differences was applied, with accommodation of sometimes heavy censoring (nondetection) in either device. The resulting estimates of bias and standard deviation of the OVM relative to the CAN were computed by tertile of the canister-measured concentration. In general, OVM and CAN measurements were in the best agreement for benzene and other aromatic compounds with hydrocarbon additions (ethylbenzene, toluene, and xylenes). The two methods were not in such good agreement for styrene and halogenated compounds (carbon tetrachloride, p-dichlorobenzene, methylene chloride, and trichloroethylene). OVMs slightly overestimated benzene concentrations and carbon tetrachloride at low concentrations, but in all other cases where significant differences were found, OVMs underestimated relative to canisters. Our study indicates that the two methods are in agreement for some compounds, but not all. We provide data and interpretation on the relative performance of the two VOC measurement methods, which facilitates intercomparisons among studies

Schmitt, M., Thoni, L., Waldner, P., Thimonier, A., 2005. Total deposition of nitrogen on Swiss long-term forest ecosystem research (LWF) plots: comparison of the throughfall and the inferential method. *Atmospheric Environment* 39 (6), 1079-1091.

The total deposition of nitrogen was estimated at 10 plots in the Swiss Long-Term Forest Ecosystem Research Programme for 1 year (1999/2000) using two methods: (1) the throughfall method, using bulk precipitation and throughfall measurements as input data for

the canopy budget model; and (2) the inferential method, based on measurements of ammonia and nitrogen dioxide with passive samplers and deposition velocities taken from literature. The inferential method was coupled with a regression model deriving the other terms of the total deposition of nitrogen (wet deposition.. dry deposition of nitric acid and dry deposition of particulate nitrogen) from measurements of the bulk deposition of nitrogen. The two methods gave estimates of the total deposition that correlated significantly with each other, in the range of 5-38 kg ha⁻¹ a⁻¹), but the inferential method tended to yield higher estimates than those obtained with the throughfall method (median difference +2.4kg ha⁻¹ a⁻¹)). In view of the overall agreement of the two methods, the use of passive samplers in the open, coupled with the measurement of bulk deposition, appears, under certain conditions, to be an interesting alternative to the throughfall method. (C) 2004 Elsevier Ltd. All rights reserved

Scudlark, J.R., Jennings, J.A., Roadman, M.J., Savidge, K.B., Ullman, W.J., 2005. Atmospheric nitrogen inputs to the Delaware Inland Bays: the role of ammonia. *Environmental Pollution* 135 (3), 433-443.

A previous assessment of nitrogen loading to the Delaware Inland Bays indicates that atmospheric deposition provides 15-25% of the total, annual N input to these estuaries. A large and increasing fraction of the atmospheric wet flux is NH₄⁺, which for most aquatic organisms represents the most readily assimilated form of this nutrient. Particularly noteworthy is a 60% increase in the precipitation NH₄⁺ concentration at Lewes, DE over the past 20 years, which parallels the increase in poultry production on the Delmarva Peninsula over this period (currently standing at nearly 585 million birds annually). To further examine the relationship between local NH₃ emissions and deposition, biweekly-integrated gaseous NH₃ concentrations were determined using Ogawa passive samplers deployed at 13 sampling sites throughout the Inland Bays watershed over a one-year period. Annual mean concentrations at the 13 sites ranged from < 0.5 µg NH₃ M to > 6 µg NH₃ M, with a mean of 1.6 ± 1.0 µg NH₃ m⁻³. At most sites, highest NH₃ concentrations were evident during spring and summer, when fertilizer application and poultry house ventilation rates are greatest, and seasonally elevated temperatures induce increased rates of microbial activity and volatilization from soils and animal wastes. The observed north-to-south concentration gradient across the watershed is consistent with the spatial distribution of poultry houses, as revealed by a GIS analysis of aerial photographs. Based on the average measured NH₃ concentration and published NH₃ deposition rates to water surfaces (5-8 mm s⁻¹), the direct atmospheric deposition of gaseous NH₃ to the Inland Bays is 3.0-4.8 kg ha⁻¹ yr⁻¹). This input, not accounted for in previous assessments of atmospheric loading to the Inland Bays, would effectively double the estimated direct dry deposition rate, and is on par with the NO₃⁻ and NH₄⁺ wet fluxes. A second component of this study examined spatial differences in NO₃⁻ and NH₄⁺ wet deposition 3-4 within the Inland Bays watershed. In a pilot study, precipitation composition at the Lewes NADP-AIRMoN site (DE 02) was compared with that at a satellite site established at Riverdale on the Indian River Estuary, approximately 21 km southwest. While the volume-weighted mean precipitation NO₃⁻ concentrations did not differ significantly between sites, the NH₄⁺ concentration observed at Riverdale (26.3 µmoles L⁻¹) was 73% greater than at Lewes (15.2 µmoles L⁻¹). More recently, a NADP site was established at Trap Pond, DE (DE 99), which was intentionally located within the region of intense poultry production. A comparison of the initial two years (6/2001-5/2003) of precipitation chemistry data from Trap Pond with other nearby NADP-AIRMoN sites (Lewes and Smith Island) reveals fairly homogeneous NO₃⁻ wet deposition, but significant spatial differences (similar to 60%) in the NH₄⁺ wet flux. Overall, these results suggest that local emissions and below-cloud scavenging provide a significant contribution to regional atmospheric N deposition. (c) 2004 Elsevier Ltd. All rights reserved

Shen, L., Wania, F., Lei, Y.D., Teixeira, C., Muir, D.C.G., Bidleman, T.F., 2005. Atmospheric distribution and long-range transport behavior of organochlorine pesticides in north America. *Environmental Science & Technology* 39 (2), 409-420.

Annually averaged concentrations and enantiomeric compositions of organochlorine pesticides (OCPs) in air were determined in 2000/2001 at 40 stations across North America using XAD-based passive samplers. Absolute concentration differences across the continent, the skewness and kurtosis of the concentration distribution, the relative abundance of parent compound and metabolites, and the chiral signatures can identify regional sources of OCP to the atmosphere. Specifically, air samples collected in the southeastern United States had elevated concentrations of chlordane-related compounds, higher ratios of transo cis-chlordane and heptachlor to heptachlor epoxide, as well as higher enantiomeric fractions of trans-chlordane as compared to other regions, suggesting continued release of microbially unprocessed chlordane to the regional atmosphere. Similarly, greatly elevated concentrations of p,p'-DDT, low relative abundance of the metabolite DDE, and a racemic composition of o,p'-DDT in samples from southern Mexico and Belize indicate recent use of DDT in these regions. Belize is also a potential source region for dieldrin. Reflecting its continued use in North America, endosulfan is now one of the most abundant and ubiquitous UPS in the continental atmosphere. In contrast to these OCPs, air concentrations of penta- and hexachlorobenzene vary only by factors of 2-4 across the continent, reflecting a long atmospheric residence time and few primary sources. Atmospheric levels of the chlorobenzenes, (x-endosulfan, and p,p'-DDE increase with elevation in the Canadian Rocky Mountains. Empirical travel distances for the OCPs derived from latitudinal concentration profiles are in good agreement with model-derived indicators of long-range transport potential and, in particular, lead to a similar categorization of the OCPs. Large-scale passive air sampling networks are suitable for monitoring compliance with, and effectiveness

of, regulatory control measures and for establishing experimentally the atmospheric long-range transport behavior of organic air pollutants

Soderstrom, H., Hajslova, J., Kocourek, V., Siegmund, B., Kocan, A., Obiedzinski, W., Tysklind, M., Bergqvist, P.A., 2005. PAHs and nitrated PAHs in air of five European countries determined using SPMDs as passive samplers. *Atmospheric Environment* 39 (9), 1627-1640.

The gas phase polycyclic aromatic hydrocarbons (PAHs) and nitro-PAHs in the atmosphere of five European countries (Austria, the Czech Republic, Poland, Slovakia and Sweden) were measured simultaneously during two 21-day passive sampling campaigns using semipermeable membrane devices (SPMDs). SPMD samplers, consisting of a pair of SPMDs covered by a metal umbrella, were deployed at 40 locations ranging from remote and rural to urban and industrial, at a similar time during each of the two sampling campaigns (autumn 1999, except in Poland, winter 1999, and summer 2000). The total amounts of PAHs and nitro-PAHs found in the SPMDs ranged between $5.0\text{--}1.2 \times 10^3$ and $1.1 \times 10^{-3}\text{--}4.0$ ng SPMD⁻¹ day⁻¹, respectively. The measured environmental sampling conditions were similar between sites and, thus, the variations in the SPMD data reflected the spatial differences in gas phase concentrations of nitro-PAHs and PAHs within and between countries. The gas phase concentrations of nitro-PAHs and PAHs found in East Europe (Slovakia, the Czech Republic and Poland 1999) were 10 times higher than those measured in Sweden, Austria and Poland in 2000. In each country, the levels of PAHs and nitro-PAHs differed by one-three orders of magnitudes amongst sampling sites. The highest within-country spatial differences were found in Poland where levels of PAHs and nitro-PAHs were about one and two orders of magnitudes, respectively, higher in winter 1999 than in summer 2000, probably due to increasing emissions of coal combustion for residential heating. Differences in PAH-patterns between sites were visualized by the multivariate projection method, principal component analysis (PCA). However, no specific source patterns were found, probably since imissions rather than emissions were measured, so the PAHs detected at many sites originated from multiple sources. (c) 2004 Elsevier Ltd. All rights reserved

Strandberg, B., Sunesson, A.L., Olsson, K., Levin, J.O., Ljungqvist, G., Sundgren, M., Sallsten, G., Barregard, L., 2005. Evaluation of two types of diffusive samplers and adsorbents for measuring 1,3-butadiene and benzene in air. *Atmospheric Environment* 39 (22), 4101-4110.

1,3-Butadiene and benzene are common air pollutants, the former being a suspected and the latter an established carcinogen. Road traffic and industry emissions are sources of these compounds. In order to assess the risk posed to the general population by ambient levels of these pollutants, diffusive samplers capable of monitoring them over both long timescales (weeks) and shorter periods (8-24h) are needed. In this study, we evaluated a new diffusive sampler, the SKC-Ultra, and a partially validated sampler, the Radiello, both of which are compatible with thermal desorption. Two adsorbents, the graphitized carbon blacks Carbopack X and Carbograph 5, were also evaluated. Standard atmospheres of the target compounds were generated in order to determine uptake rates and to evaluate the effects of concentration, relative humidity, reverse-diffusion and storage of samplers. The samplers and adsorbents were also tested in a field study. Analysis and detection were performed using an automatic thermal desorber (ATD) connected to a gas chromatograph-flame ionization detector (GC/FID). Both samplers showed much higher uptake rates (ca. 25-50 fold) than those reported for the Perkin-Elmer sampler. The 24 h uptake rates for 1,3-butadiene and benzene obtained using the SKC-Ultra filled with Carbopack X were 14.9 ± 0.8 (SD) and 16.0 ± 1.4 (SD) mL min⁻¹, respectively, and the corresponding figures for the Radiello were 22.0 ± 0.9 (SD) and 30.4 ± 1.1 (SD) mL min⁻¹. Varying the atmospheric concentrations of the compounds had no effect on the uptake rate for the Carbopack X adsorbent and the samplers could be stored up to one month after sampling. Uptake rates of 1,3-butadiene declined over longer periods (one week). This was probably due to reverse diffusion, and the effect was less pronounced with the SKC-Ultra sampler. In summary, we consider the two samplers to be suitable both for stationary and personal monitoring of 1,3-butadiene and benzene, for the general population and for workplaces. (c) 2005 Elsevier Ltd. All rights reserved

Ta, W.Q., Wei, C., Chen, F.H., 2005. Long-term measurements of SO₂ dry deposition over Gansu Province, China. *Atmospheric Environment* 39 (37), 7095-7105.

Potassium carbonate sulfation plates, monitored monthly for 11 years from 48 sites in 11 cities in Gansu Province, China, provide a crude estimate of cumulative SO₂ dry depositions. Measured SO₂ dry deposition rates were 1.6-472mgm⁻² day⁻¹ and had seasonal variations with maxima in winter and minima mainly during summer as a result of higher winter and lower summer SO₂ concentrations. The 11-year monthly average SO₂ dry deposition rates are 23.2-248.97 and 11.7-175.6 mg m⁻² day⁻¹ in the eleven cities in winter and summer, respectively. A monthly average SO₂ deposition velocity was also estimated from 0.06 to 9.72 cm s⁻² in the 11 cities studied with a 11-year average maximum value of about 1. 1-2.7 cm s⁻² in April and July and a 11-year average minimum value of about 0.2-1.0 cm, s⁻¹ in January. The SO₂ dry deposition velocity also exhibits an increasing with wind speed in basins of less than 500 mm annual precipitation. In contrast, due to influences of the relative humidity in valleys of more than 500 mm annual precipitation, it shows a decreasing trend with wind speed increasing. (c) 2005 Elsevier Ltd. All rights reserved

Van Drooge, B.L., Grimalt, J.O., Booij, K., Camarero, L., Catalan, J., 2005. Passive sampling of atmospheric organochlorine compounds by SPMDs in a remote high mountain area. *Atmospheric Environment* 39 (28), 5195-5204.

Semi-permeable membrane devices (SPMDs) have been deployed in high mountain areas (Central Pyrenees, Catalonia, Spain) for the measurement of atmospheric concentrations of hexachloro benzene (HCB) and polychlorobiphenyls (PCBs) over a period of 1.5 years. These devices were filled with triolein and have been deployed at three altitudes, 1600, 2240 and 2600 m above sea level. Performance reference compounds were used to calibrate their sampling rates. The SPMD results were validated by comparison to active air sampling with high-volume systems. Sampling rates between 0.55 and 1.3 m³ d⁻¹ were estimated from the dissipation of PCB155. Atmospheric concentrations measured by SPMDs were in good agreement with the levels obtained by high-volume sampling. These findings suggest that SPMDs can be useful monitoring systems for the atmospheric concentrations of organochlorine compounds in remote high mountain areas. (c) 2005 Elsevier Ltd. All rights reserved

Welch, D.C., Colls, J.J., Demmers, T.G.M., Wathes, C.M., 2005. A methodology for the measurement of distributed agricultural sources of ammonia outdoors - Part 2: field validation and farm measurements. *Atmospheric Environment* 39 (4), 673-684.

Recurved passive ammonia flux (PAF) samplers based on absorption by oxalic acid were evaluated in two contrasting field environments. First, a flux frame 12 m high and 55.2 m long was used to support a vertical array of up to 156 flux samplers downwind of a controlled point or line source of ammonia (NH₃). The upwind distance of the NH₃ source was chosen so that the whole NH₃ plume was captured by the flux frame. These measurements were used to calibrate the flux frame's collection efficiency (CE). The plume dispersion was modelled with ADMS. Second, individual columns of seven flux samplers at heights between 0.3 and 10.4 m were used to measure the NH₃ emissions from a free-range sow paddock. The controlled release measurements gave measured overall CEs of over 80% and strong agreement between the measured and modelled flux densities ($R^2 > 0.9$). The farm measurements showed that this method is insufficiently sensitive for use in a climate for which the wind direction and other critical meteorological parameters may vary widely throughout the several days required for a measurement. (C) 2004 Elsevier Ltd. All rights reserved

Welch, D.C., Colls, J.J., Demmers, T.G.M., Wathes, C.M., 2005. A methodology for the measurement of distributed agricultural sources of ammonia outdoors - Part 1: validation in a controlled environment. *Atmospheric Environment* 39 (4), 663-672.

A flux frame method using recurved passive ammonia flux (PAF) samplers for the measurement of distributed outdoor agricultural sources of ammonia (NH₃) was evaluated in a controlled environment. The collection efficiency of the samplers was determined in a wind tunnel at controlled values of NH₃ flux density (0.77-13.5 mg NH₃ m⁻² s⁻¹), and over a range of angles of orientation to the flow direction (0degrees, 30degrees, 60degrees, 70degrees, 80degrees and 90degrees). The samplers were effective up to a wind speed of 7 in s⁻¹ and an angle of 80degrees with a mean collection efficiency of 71%. The flux frame method had a mean collection efficiency of 87.4% when used with ground level point sources under controlled conditions in an open-circuit wind tunnel with boundary layer airflow characteristics. (C) 2004 Elsevier Ltd. All rights reserved

Bartkow, M.E., Hawker, D.W., Kennedy, K.E., Muller, J.F., 2004. Characterizing uptake kinetics of PAHs from the air using polyethylene-based passive air samplers of multiple surface area-to-volume ratios. *Environmental Science & Technology* 38 (9), 2701-2706.

Polyethylene passive sampling devices (PSDs) were deployed to investigate how passive samplers of multiple surface area-to-volume ratios could be used to characterize uptake kinetics for polyaromatic hydrocarbons (PAHs). Theoretically, uptake profiles for different thickness PSDs of the same surface area should show the following: where uptake is linear, the amount of compound accumulated in the different PSDs will be the same and where equilibrium is approached, the amount accumulated by the different PSDs will be proportional to sampler thickness. Polyethylene sheets of the same surface area and approximately 100 and 200 µm thickness were collected after 30, 60, and 90 days of exposure along with samples from a codeployed high volume sampler. Twelve priority pollutant PAHs could be routinely quantified in replicate PSDs. Overall, reproducibility between replicate PSDs was satisfactory, with normalized differences rarely exceeding 25%. The smallest analytes quantified, fluorene, phenanthrene, and anthracene, were shown to approach equilibrium during the deployment period, whereas uptake for fluoranthene and pyrene moved into the curvilinear stage. For most of the larger molecular weight PAHs such as indeno[1,2,3-cd]pyrene, uptake could be described using a linear uptake model. Preliminary sampling rates for the compounds which remained in the linear stage of uptake ranged between 0.5 and 1.5 m³ d⁻¹ dm⁻². Sampler to air partition coefficients were estimated for PAHs which approached equilibrium and predicted for some of the other compounds. Results suggest that a single deployment of PSDs with multiple surface area-to-volume ratios can be sufficient to determine whether uptake was linear or approaching equilibrium for a range of PAHs

Bartkow, M.E., Huckins, J.N., Muller, J.F., 2004. Field-based evaluation of semipermeable membrane devices (SPMDs) as passive air samplers of polyaromatic hydrocarbons (PAHs). *Atmospheric Environment* 38 (35), 5983-5990.

Semipermeable membrane devices (SPMDs) have been used as passive air samplers of semivolatile organic compounds in a range of studies. However, due to a lack of calibration data for polyaromatic hydrocarbons (PAHs), SPMD data have not been used to estimate air concentrations of target PAHs. In this study, SPMDs were deployed for 32 days at two sites in a major metropolitan area in Australia. High-volume active sampling systems (HiVol) were co-deployed at both sites. Using the HiVol air concentration data from one site, SPMD sampling rates were measured for 12 US EPA Priority Pollutant PAHs and then these values were used to determine air concentrations at the second site from SPMD concentrations. Air concentrations were also measured at the second site with co-deployed HiVols to validate the SPMD results. PAHs mostly associated with the vapour phase (Fluorene to Pyrene) dominated both the HiVol and passive air samples. Reproducibility between replicate passive samplers was satisfactory ($CV < 20\%$) for the majority of compounds. Sampling rates ranged between 0.6 and 6.1 $m(3) d(-1)$. SPMD-based air concentrations were calculated at the second site for each compound using these sampling rates and the differences between SPMD-derived air concentrations and those measured using a HiVol were, on average, within a factor of 1.5. The dominant processes for the uptake of PAHs by SPMDs were also assessed. Using the SPMD method described herein, estimates of particulate sorbed airborne PAHs with five rings or greater were within 1.8-fold of HiVol measured values. (C) 2004 Elsevier Ltd. All rights reserved

Bertoni, G., Ciuchini, C., Tappa, R., 2004. Measurement of long-term average carbon dioxide concentrations using passive diffusion sampling. *Atmospheric Environment* 38 (11), 1625-1630.

A diffusive sampling device is proposed for long-term determination of average airborne concentration Of CO₂ in urban and industrial areas, as well as in indoor sites. A hydro-alcoholic barium hydroxide solution is employed as a CO₂ reagent sink. The analytical method is based on the determination of the solute barium hydroxide remained after the acid-base reaction, in which its insoluble carbonate salt precipitates. Indoor laboratory experiments show that this technique exhibits a good precision and reproducibility. A 6-week internal consistency test demonstrates that this device has a constant uptake rate, allowing us to propose it as a suitable and inexpensive tool in performing the monitoring of urban and industrial sites over long periods and in indoor-outdoor studies, like those involved in the sick-building syndrome problem. (C) 2003 Elsevier Ltd. All rights reserved

Cruz, L.P.S., Campos, V.P., Silva, A.M.C., Tavares, T.M., 2004. A field evaluation of a SO₂ passive sampler in tropical industrial and urban air. *Atmospheric Environment* 38 (37), 6425-6429.

Passive samplers have been widely used for over 30 years in the measurement of personal exposure to vapours and gases in the workplace. These samplers have just recently been applied in the monitoring of ambient air, which presents concentrations that are normally much smaller than those found in occupational environments. The locally constructed passive sampler was based on gas molecular diffusion through static air layer. The design used minimizes particle interference and turbulent diffusion. After exposure, the SO₂ trapped in impregnated filters with Na₂CO₃ was extracted by means of an ultrasonic bath, for 15 min, using $1.0 \times 10(-2)$ mol L⁻¹ H₂O₂. It was determined as SO₄-2 by ion chromatography. The performance of the passive sampler was evaluated at different exposure periods, being applied in industrial and urban areas. Method precision as relative standard deviation for three simultaneously applied passive samplers was within 10%. Passive sampling, when compared to active monitoring methods under real conditions, used in urban and industrial areas, showed an overall accuracy of 15%. A statistical comparison with an active method was performed to demonstrate the validity of the passive method. Sampler capacity varied between 98 and 421 μg SO₂ $m(-3)$ for exposure periods of one month and one week, respectively, which allows its use in highly polluted areas. (C) 2004 Elsevier Ltd. All rights reserved

Divine, C.E., Mccray, J.E., 2004. Estimation of membrane diffusion coefficients and equilibration times for low-density polyethylene passive diffusion samplers. *Environmental Science & Technology* 38 (6), 1849-1857.

Passive diffusion (PD) samplers offer several potential technical and cost-related advantages, particularly for measuring dissolved gases and volatile organic compounds (VOCs) in groundwater at contaminated sites. Sampler equilibration is a diffusion-type process; therefore, equilibration time is dependent on sampler dimensions, membrane thickness, and the temperature-dependent membrane diffusion coefficient (D-m) for the analyte of interest. Diffusion coefficients for low-density polyethylene membranes were measured for He, Ne, H-2, O-2, and N-2 in laboratory experiments and ranged from 1.1 to $1.9 \times 10(-7)$ $cm(2) sec(-1)$ (21 degreesC). Additionally, D-m values for several commonly occurring VOCs were estimated from empirical experimental data previously presented by others (Vroblesky, D. A.; Campbell, T. R. *Adv. Environ. Res.* 2001, 5 (1), 1.), and estimated values ranged from 1.7 to $4.4 \times 10(-7)$ $cm(2) sec(-1)$ (21 degreesC). On the basis of these D-m ranges, PD sampler equilibration time is predicted for various sampler dimensions, including dimensions consistent with simple constructed samplers used in this study and commercially available samplers. Additionally, a numerical model is presented that can be used to evaluate PD sampler concentration "lag time" for

conditions in which in situ concentrations are temporally variable. The model adequately predicted lag time for laboratory experiments and is used to show that data obtained from appropriately designed PD samplers represent near-instantaneous measurement of in situ concentrations for most field conditions

Franklin, A.C., Salmon, L.G., Wolfson, J.M., Christoforou, C.S., 2004. Ozone measurements in South Carolina using passive samplers. *Journal of the Air & Waste Management Association* 54 (10), 1312-1320

Harner, T., Shoeib, M., Diamond, M., Stern, G., Rosenberg, B., 2004. Using passive air samplers to assess urban - Rural trends for persistent organic pollutants. 1. Polychlorinated biphenyls and organochlorine pesticides. *Environmental Science & Technology* 38 (17), 4474-4483.

Passive air samplers were used to investigate urban-rural differences of polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) over an integrated time period. Samplers consisting of polyurethane foam (PUF) disks and semi-permeable membrane devices (SPMDs) were housed in protective chambers and deployed at six sites for a 4 month duration in the summer of 2000. The sampling transect originated in downtown Toronto and extended similar to 75 km northward into a rural region. Results for the two types of samplers agreed well with one another. Higher blank levels were encountered for the SPMDs, especially for the OCPs, whereas blanks were very low for the PUF disks. Passive sampler-derived air concentrations were consistent with previous measurements of PCBs and OCPs in the region. The largest urban-rural gradient was observed for PCBs (similar to 5-10 times). Chlordanes also showed an urban-rural gradient, possibly reflecting past usage of chlordane on residential lawns and emissions from treated house foundations. Other OCPs exhibited a rural-urban gradient (dieldrin, endosulfan 1, and DDT isomers), which was attributed either to off-gassing from previously treated agricultural soils (dieldrin and DDTs) or to continued usage in agriculture (endosulfan 1). The results of this study demonstrated the feasibility of using such devices to determine air concentrations of persistent organic pollutants (POPs) and to assess their spatial distribution for time integrated samples. Data such as this is essential for: model validation and for process research and addressing international monitoring strategies on POPs

Hazenkamp-von Arx, M.E., Gotschi, T., Ackermann-Liebrich, U., Bono, R., Burney, P., Cyrus, J., Jarvis, D., Lillienberg, L., Luczynska, C., Maldonado, J.A., Jaen, A., de Marco, R., Mi, Y.H., Modig, L., Bayer-Oglesby, L., et al., 2004. PM_{2.5} and NO₂ assessment in 21 European study centres of ECRHS II: annual means and seasonal differences. *Atmospheric Environment* 38 (13), 1943-1953.

The follow-up of cohorts of adults from more than 20 European centres of the former ECRHS I (1989-1992) investigates long-term effects of exposure to ambient air pollution on respiratory health, in particular asthma and change of pulmonary function. Since PM_{2.5} is not routinely monitored in Europe, we measured PM_{2.5} concentrations in 21 participating centres to estimate 'background' exposure in these cities. Winter (November-February), summer (May-August) and annual mean (all months) values of PM_{2.5} were determined from measuring periods between June 2000 and November 2001. Sampling was conducted for 7 days per month for a year. Annual and winter mean concentrations of PM_{2.5} vary substantially being lowest in Iceland and highest in centres in Northern Italy. Annual mean concentrations ranged from 3.7 to 44.9 µg m⁻³, winter mean concentrations from 4.8 to 69.2 µg m⁻³, and summer mean concentrations from 3.3 to 23.1 µg m⁻³. Seasonal variability occurred but did not follow the same pattern across all centres. Therefore, ranking of centres varied from summer to winter. Simultaneously, NO₂ concentrations were measured using passive sampling tubes. Annual mean NO₂ concentrations range from 4.9 to 72.1 µg m⁻³ with similar seasonal variations across centres and constant ranking of centres between seasons. The correlation between annual NO₂ and PM_{2.5} concentrations is fair (Spearman correlation coefficient $r(s) = 0.75$), but when considered as monthly means the correlation is far less consistent and varies substantially between centres. The range of PM_{2.5} mass concentrations obtained in ECRHS II is larger than in other current cohort studies on long-term effects of air pollution. This substantial variation in PM_{2.5} exposure will improve statistical power in future multilevel health analyses and to some degree may compensate for the lack of information on within-city variability. Seasonal means may be used to indicate potential differences in the toxicity across the year. Across ECRHS cities annual NO₂ might serve as a surrogate for PM_{2.5}, especially for past exposure assessment, when PM_{2.5} is not available. (C) 2004 Elsevier Ltd. All rights reserved

Kim, S.T., Maeda, Y., Tsujino, Y., 2004. Assessment of the effect of air pollution on material damages in Northeast Asia. *Atmospheric Environment* 38 (1), 37-48.

Material exposure tests have been carried out to evaluate the relationship between air pollution and material damage, with the cooperation of researchers in Japan, China and Korea, since 1993. Test materials such as bronze, copper, marble, and steel have been exposed to both unsheltered and rain-sheltered outdoor conditions, with the simultaneous passive sampler measurement of SO₂ and NO₂ concentrations, at 17 separate sampling sites in East Asia. Meteorological data were gathered from the AWS in each country, and the chemical compositions of wet deposition analyzed by bulk sampling of the monthly rainfall. As a result, the corrosion rates of the

test materials in ambient air were found to be in the order: carbon steel > marble > bronze greater than or equal to copper. The corrosion rates of test materials in the unsheltered outdoor conditions were 2.28-6.24 times larger than those under the rain-sheltered conditions. The rates of corrosion were also found to be the highest in the heavily polluted areas of China, with these rates for the metal pieces generally being proportional to the SO₂ concentration. With the two Korean sites, the test pieces at the Daegu site displayed higher rates of corrosion, possibly due to the higher SO₂ concentration. (C) 2003 Elsevier Ltd. All rights reserved

Krzyzanowski, J., 2004. Ozone variation with height in a forest canopy - results from a passive sampling field campaign. *Atmospheric Environment* 38 (35), 5957-5962.

Vertical ozone profiles were measured using a 10.5 m tower in a low (13 m) forest canopy in the Lower Fraser Valley, British Columbia, Canada. Ozone was measured cumulatively using passive samplers over five 2-week periods, at seven canopy heights. A strong power-law relationship was found between biweekly mean hourly ozone concentration and within-canopy height ($r^2 = 0.98-0.99$), with a 31-47% reduction in ozone towards the forest floor. Using a Buckingham-Pi dimensional analysis the plots were normalised. Through similarity theory the equation $y = 1.03x(0.15b)$ was derived for ozone concentration with canopy height; where y is normalised biweekly mean hourly ozone, x is height normalised by the height of the canopy, and b is a stability parameter that increases with increased stability. This study presents a unique method of measuring within-canopy ozone that is inexpensive, yields good results, and may be further developed for flux estimation. (C) 2004 Elsevier Ltd. All rights reserved

Lan, T.T.N., Nishimura, R., Tsujino, Y., Imamura, K., Warashina, M., Hoang, N.T., Maeda, Y., 2004. Atmospheric concentrations of sulfur dioxide, nitrogen oxides, ammonia, hydrogen chloride, nitric acid, formic and acetic acids in the south of Vietnam measured by the passive sampling method. *Analytical Sciences* 20 (1), 213-217.

A passive sampling method was applied to measure the concentrations of air pollutants., such as sulfur dioxide, nitrogen oxides, ammonia, hydrogen chloride, and nitric, formic and acetic acids, in the ambient air at four test sites in the southern region of Vietnam. The monthly averages and the average concentrations of air pollutants during the period from July 2001 to September 2002 are reported here. The concentrations of air pollutants varied widely, depending on the test sites and the sampling periods. The average concentrations of sulfur dioxide in the air during the period from July 2001 to September 2002 at the four test sites were 3.3 - 16.9 ppb, and those of nitrogen dioxide were 5.4 - 12.8 ppb. The concentrations of nitrogen monoxide and hydrogen chloride were very low at all of the test sites. The observed concentrations of all of the above-mentioned pollutants were lower than those of the Vietnamese standards of air pollutants

Lehndorff, E., Schwark, L., 2004. Biomonitoring of air quality in the Cologne Conurbation using pine needles as a passive sampler - Part II: polycyclic aromatic hydrocarbons (PAH). *Atmospheric Environment* 38 (23), 3793-3808.

Emissions from fossil fuel combustion pose a serious threat to public health and impose the need for an improved monitoring of polycyclic aromatic hydrocarbons (PAH), a major class of persistent organic pollutants. For this purpose, utilization of evergreen conifers offers significant biomonitoring potential. In part I of this series we inspected the load of combustion derived magnetic particles in pine needles from 43 locations of the Cologne Conurbation, Germany; we here report the corresponding PAH concentrations and distribution patterns. Concentrations (dry weight) of summed 3-6-ring PAH range between 51 and 410 ng g⁻¹ with a median of 123.8 ng g⁻¹; thus being in agreement with other urban studies. Phenanthrene was the dominating PAH with median concentrations of 47 ng g⁻¹ followed by fluoranthene and pyrene at 22 and 13 ng g⁻¹, respectively. The major proportion of PAH was attributed to traffic sources, with minor contribution from power plant, domestic heating, industrial, and vegetation burn emissions. Significant differences between major and minor roads were not observed indicating a thorough mixing of PAH-loaded air masses in the Cologne Conurbation. Needles in inner city parks gave much higher PAH concentrations than those in suburban green areas. Although distribution patterns of PAH were variable a PAH source reconciliation based on isomer compositions is difficult, due to thorough mixing of air masses and associated loss of source specificity. Ambient air monitoring in urban areas based on persistent organic pollutant load of vegetation is a feasible and cost effective way of controlling environmental quality. (C) 2004 Elsevier Ltd. All rights reserved

Mukerjee, S., Smith, L.A., Norris, G.A., Morandi, M.T., Gonzales, M., Noble, C.A., Neas, L.M., Özkaynak, A.H., 2004. Field method comparison between passive air samplers and continuous monitors for VOCs and NO₂ in El Paso, Texas. *Journal of the Air & Waste Management Association* 54 (3), 307-319

Perrino, C., Catrambone, M., 2004. Development of a variable-path-length diffusive sampler for ammonia and evaluation of ammonia pollution in the urban area of Rome, Italy. *Atmospheric Environment* 38 (38), 6667-6672.

A variable-path-length diffusive sampler for the determination of atmospheric ammonia was developed and tested. Polyethylene was found to be the best material for the construction of the sampler, while a glass body sampler of similar design yielded unreliable results; phosphorous acid was the best collecting medium. The low level of the field blanks and the high operative capacity make this device able to operate in a very wide loading range (0.3-100 μg); the possibility to vary the length of the diffusive pathway allows a further increase of the detectable concentration range (0.1-125 $\mu\text{g m}^{-3}$) during a 1-month exposure). Reproducibility is better than 5% and the comparison with reference denuders demonstrated a good accuracy of the method (deviation lower than 5%). The deployment of these samplers in some field campaigns carried out in Rome allowed us to confirm the close link between ammonia concentration and traffic emission and to get an insight into the spatial variability of this pollutant. (C) 2004 Elsevier Ltd. All rights reserved

Plaisance, H., 2004. Response of a Palmes tube at various fluctuations of concentration in ambient air. Atmospheric Environment 38 (36), 6115-6120.

The sampling of the Palmes tube is based on the principle of molecular diffusion. Its response at fluctuating concentrations can be analysed theoretically using a mathematical methodology defined by Hearl and Manning (American Industrial Hygiene Association Journal 41 (1980) 778) to resolve Fick's second law of diffusion. First, this paper details all the equations used in this theoretical approach. Then, this methodology is applied to various patterns of concentration variations commonly encountered in outdoor environments. The errors of the Palmes tube are then computed numerically and discussed in accordance with the characteristics of the concentration variation: the peak duration and the ratio of the peak amplitude to the background concentration. Although fast fluctuations (about a few minutes) of high amplitude (for example, above 200 $\mu\text{g m}^{-3}$) induce temporal overestimations in the tube response, their contributions to the mean concentration estimated over the 14-day sampling time can be considered as negligible. (C) 2004 Elsevier Ltd. All rights reserved

Plaisance, H., Plechocki-Minguy, A., Garcia-Fouque, S., Galloo, J.C., 2004. Influence of meteorological factors on the NO₂ measurements by passive diffusion tube. Atmospheric Environment 38 (4), 573-580.

This paper describes the results of experiments in exposure chamber to determine the effects of wind velocity, temperature and relative humidity on the performances of Palmes tube, for measuring nitrogen dioxide in the outdoor environments. A total of 86 Palmes tubes were exposed at various conditions: wind velocities ranging from 0.15 to 2.3 ms^{-1} , temperatures from 2°C to 40°C and relative humidities from 20% to 85%. The main information is the high increase of sampling rate with increasing wind velocity. The formation of eddies at the open end of tube induces a reduction in the effective length of diffusion. This reduction starts up from the weak velocities of wind (i.e. 0.3 m/s) and is estimated at 47% for 2 ms^{-1} . Influences of temperature and relative humidity give the weak deviations, exceeding 10% only under unusual conditions ($T > 30^\circ\text{C}$ and $\text{RH} > 80\%$). Under common conditions, the sampling rate regularly increases to 0.3%/°C with temperature. Some practical solutions are proposed in this study to improve the accuracy of measurements. The use of a protective device and application of a corrective function appears through these results as effective means to correct the effects of meteorological factors on the sampling rate of tube. (C) 2003 Elsevier Ltd. All rights reserved

Pozo, K., Harner, T., Shoeib, M., Urrutia, R., Barra, R., Parra, O., Focardi, S., 2004. Passive-sampler derived air concentrations of persistent organic pollutants on a north-south transect in Chile. Environmental Science & Technology 38 (24), 6529-6537.

Passive air samplers consisting of polyurethane foam (PUF) disks, were deployed in six locations in Chile along a north-south transect to investigate gas-phase concentrations of polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs), and polybrominated diphenyl ethers (PBDEs). The study provides new information on air concentrations of these persistent organic pollutants (POPs) which is lacking in this region. It also provides insight into potential sources and long-range transport (LRT). The samplers were deployed for a 2-month period in five remote sites and one site in the city of Concepcion. Mean concentrations (pg m^{-3}) for SigmaPCB were 4.7 \pm 2.7 at remote sites and 53 \pm 13 in Concepcion. PCB levels at remote sites were related to proximity to urban source regions and/or air back trajectories. With the exception of endosulfan I, mean concentrations (pg m^{-3}) of OCPs at background sites were consistently low: 5.4 \pm 1.4 for α -HCH, 7.0 \pm 1.1 for γ -HCH, 2.5 \pm 0.5 for TC, 2.5 \pm 0.6 for CC, 1.9 \pm 1.2 for dieldrin, and less than 3.5 for toxaphene. Endosulfan I showed a decreasing concentration gradient from 99 to 3.5 pg m^{-3} from the north to south of Chile. Concentrations of OCPs in the Concepcion City were generally 10-20 times higher than at the background sites suggesting continued usage and/or re-emission from past use. For instance, at remote sites, the α/γ ratio (0.76) was; typical of background air, while the ratio in Concepcion (0.12) was consistent with fresh use of γ -HCH. Levels of SigmaPBDEs were below the detection limit of 6 pg m^{-3} at all sites

Scholtens, R., Dore, C.J., Jones, B.M.R., Lee, D.S., Phillips, V.R., 2004. Measuring ammonia emission rates from livestock buildings and manure stores - part 1: development and validation of external tracer ratio, internal tracer ratio and passive flux sampling methods. *Atmospheric Environment* 38 (19), 3003-3015.

There is a need for robust methods for measuring ammonia emission rates from livestock buildings and manure stores, to guide efforts to abate emissions from livestock farming. This paper reports research to develop and validate three candidate measurement techniques: (a) An external tracer ratio method, where concentrations of ammonia and sulphur hexafluoride are measured downwind of an animal house or manure store. (b) An internal tracer ratio (ITR) method, suited to animal housings, where concentrations of ammonia and sulphur hexafluoride are measured just before air leaves the building. (c) A flux sampler method, which uses sets of passive flux sampling devices positioned so as to intersect all significant flows of air out of an animal house or manure store source. All three of the measurement techniques were validated at a building section simulating a naturally ventilated (space-boarded) cattle house, with the external tracer ratio method also being validated at a simulated slurry store. In the validation tests on the external tracer ratio method the derived ammonia emission rates from the slurry store and cattle house validation studies were 25% below and 43% above the measured release rate, respectively. These biases were shown by t-tests to be statistically highly significant, but no clear explanation could be found for the different signs and magnitudes in the two cases. For the ITR method, recovery rates of 78% and 101% of released NH₃ were achieved, with low and high release rates, respectively. Validation tests conducted on the flux samplers gave an average of 66% (standard deviation 2.9%) ammonia recovery. The cause of this non-ideal level of recovery has not yet been identified. However, given the low standard deviation, it was concluded that these samplers could be used to measure ammonia emission rates from real farm buildings, provided that a correction factor for the non-ideal recovery was applied. (C) 2004 Elsevier Ltd. All rights reserved

Sexton, K., Adgate, J.L., Mongin, S.J., Pratt, G.C., Ramachandran, G., Stock, T.H., Morandi, M.T., 2004. Evaluating differences between measured personal exposures to volatile organic compounds and concentrations in outdoor and indoor air. *Environmental Science & Technology* 38 (9), 2593-2602.

Accurate estimation of human exposures to volatile organic compounds (VOCs) is a key element of strategies designed to protect public health from the adverse effects of hazardous air pollutants. The focus here is on examining the capability of three different exposure metrics (outdoor community concentrations, indoor residential concentrations, and a simple time-weighted model) to estimate observed personal exposures to 14 VOCs. The analysis is based on 2-day average concentrations of individual VOCs measured concurrently in outdoor (O) air in three urban neighborhoods, indoor (I) air in participant's residences, and personal (P) air near the breathing zone of 71 healthy, nonsmoking adults. A median of four matched P-I-O samples was collected for each study participant in Minneapolis/St. Paul over three seasons (spring, summer, and fall) in 1999 using charcoal-based passive air samplers (3M model 3500 organic vapor monitors). Results show a clear pattern for the 14 VOCs, with $P > I > O$ concentrations. Intra-individual variability typically spanned at least an order of magnitude, and inter-individual variability spanned 2 or more orders of magnitude for each of the 14 VOCs. Although both O and I concentrations generally underestimated personal exposures, I concentrations provided a substantially better estimate of measured P concentrations. Mean squared error (MSE) as well as correlation measures were used to assess estimator performance at the subject-specific level, and hierarchical, mixed effects models were used to estimate the bias and variance components of MSE by tertile of personal exposure. Bias and variance both tended to increase in the upper third of the P exposure distribution for O versus P and I versus P. A simple time-weighted model incorporating measured concentrations in both outdoor community air and indoor residential air provided no improvement over I concentration alone for the estimation of P exposure

Sexton, K., Adgate, J.L., Ramachandran, G., Pratt, G.C., Mongin, S.J., Stock, T.H., Morandi, M.T., 2004. Comparison of personal, indoor, and outdoor exposures to hazardous air pollutants in three urban communities. *Environmental Science & Technology* 38 (2), 423-430.

Two-day average concentrations of 15 individual volatile organic compounds (VOCs) were measured concurrently in (a) ambient air in three urban neighborhoods, (b) air inside residences of participants, and (c) personal air near the breathing zone of 71 healthy, nonsmoking adults. The outdoor (O), indoor (I), and personal (P) samples were collected in the Minneapolis/St. Paul metropolitan area over three seasons (spring, summer, and fall) in 1999 using charcoal-based passive air samplers (3M model 3500 organic vapor monitors). A hierarchical, mixed-effects statistical model was used to estimate the mutually adjusted effects of monitor location, community, and season while accounting for within-subject and within-time-index (monitoring period) correlation. Outdoor VOC concentrations were relatively low compared to many other urban areas, and only minor seasonal differences were observed. A consistent pattern of $P > I > O$ was observed across both communities and seasons for 13 of 15 individual VOCs (exceptions were carbon tetrachloride and chloroform). Results indicate that ambient VOC measurements at central monitoring sites can seriously underestimate actual exposures for urban residents, even when the outdoor measurements are taken in their own neighborhoods

Shinohara, N., Kumagai, K., Yamamoto, N., Yanagisawa, Y., Fujii, M., Yamasaki, A., 2004. Field validation of an active sampling cartridge as a passive sampler for long-term carbonyl monitoring. *Journal of the Air & Waste Management Association* 54 (4), 419-424

Siefert, R.L., Scudlark, J.R., Potter, A.G., Simonsen, K.A., Savidge, K.B., 2004. Characterization of atmospheric ammonia emissions from a commercial chicken house on the Delmarva Peninsula. *Environmental Science & Technology* 38 (10), 2769-2778.

A three-dimensional sampling grid using passive collectors was used to characterize the downwind gas-phase ammonia plumes originating from a commercial chicken house on the Delmarva Peninsula in the Chesapeake Bay watershed. Inverse Gaussian plume modeling was used to determine the source strength of the chicken house and the corresponding chicken emission factors. A total of seven field deployments were performed during two different flocks with a sampling duration ranging from 6 to 12.6 h. The deployments occurred during weeks 3, 4, and 5 of the 6-week chicken grow-out period in the months of May-July 2002. The ammonia emission factors ranged from 0.27 to 2.17 g of NH₃-N bird⁻¹ day⁻¹ with a mean of 1.18 g of NH₃-N bird⁻¹ day⁻¹. Weighted emissions factors that accounted for the nonlinear increase in ammonia emissions over the 6-week grow-out period were also calculated and ranged from 0.14 to 1.65 g of NH₃-N bird⁻¹ day⁻¹ with a mean of 0.74 g of NH₃-N bird⁻¹ day⁻¹. These weighted emission values would correspond to an annual release of approximately 18 x 10⁶ kg of NH₃-N to the atmosphere from broiler production on the Delmarva Peninsula. This assumes that the emission factors in this study are representative for the entire year with varying meteorological conditions and are representative of all chicken husbandry practices. The Delmarva Peninsula could represent a significant source of nutrient nitrogen to the Chesapeake Bay and Delaware Bay watersheds through atmospheric deposition when considering the size of this annual release rate, the relative short atmospheric lifetime of ammonia due to deposition, and the proximity of the Delmarva Peninsula to the Chesapeake and Delaware Bays

Singer, B.C., Hodgson, A.T., Hotchi, T., Kim, J.J., 2004. Passive measurement of nitrogen oxides to assess traffic-related pollutant exposure for the East Bay Children's Respiratory Health Study. *Atmospheric Environment* 38 (3), 393-403.

The East Bay Children's Respiratory Health Study is examining associations between traffic-related pollutant exposures and respiratory health among children who reside and attend schools at varied proximity to northern California freeways. Chronic exposures are being inferred from outdoor pollutant concentrations at neighborhood schools. This paper reports primarily weeklong integrated NO₂ and NO_x concentrations measured with passive samplers placed outside at 10 elementary schools during 14 weeks in spring and 8 weeks in fall 2001. Measurements were also made outside selected student residences to examine spatial variability within three school neighborhoods. Regional concentrations of NO₂ and NO_x varied widely from week to week. School site data were normalized to measurements at a nearby regional monitoring station to facilitate analysis of relative pollutant exposures at the neighborhood schools. Normalized concentrations were consistent at each school throughout the study. Schools located upwind or far downwind of freeways were generally indistinguishable from one another and regional pollution levels. For school and neighborhood sites within 350 m downwind of a freeway, concentrations increased with decreasing downwind distance. The highest normalized concentrations occurred at a school located directly adjacent to a major freeway and a shopping center. In this case, normalized NO₂ and NO_x were similar to 60% and similar to 100% higher than regional background levels. At three schools within 130-230 m downwind of a freeway, normalized NO₂ and NO_x were similar to 20-30 % and similar to 50-80 % higher than regional levels. Validation testing of the passive samplers indicated precision of better than 5% for both NO₂ and NO_x when samplers were deployed outside for 1-week periods. Passive sampler results agreed with co-located chemiluminescence measurements to within 8% for NO₂ and 3% for NO_x. (C) 2003 Elsevier Ltd. All rights reserved

Soderstrom, H.S., Bergqvist, P.A., 2004. Passive air sampling using semipermeable membrane devices at different wind-speeds in situ calibrated by performance reference compounds. *Environmental Science & Technology* 38 (18), 4828-4834.

Semipermeable membrane devices (SPMDs) are passive samplers used to measure the vapor phase of organic pollutants in air. This study tested whether extremely high wind-speeds during a 21-day sampling increased the sampling rates of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), and whether the release of performance reference compounds (PRCs) was related to the uptakes at different wind-speeds. Five samplers were deployed in an indoor, unheated, and dark wind tunnel with different wind-speeds at each site (650 m s⁻¹). In addition, one sampler was deployed outside the wind tunnel and one outside the building. To test whether a sampler, designed to reduce the wind-speeds, decreased the uptake and release rates, each sampler in the wind tunnel included two SPMDs positioned inside a protective device and one unprotected SPMD outside the device. The highest amounts of PAHs and PCBs were found in the SPMDs exposed to the assumed highest wind-speeds. Thus, the SPMD sampling rates increased with increasing wind-speeds, indicating that the uptake was largely controlled by the boundary layer at the membrane-air interface. The coefficient of variance (introduced by the 21-day sampling and the chemical analysis) for the air concentrations of three

PAHs and three PUS, calculated using the PRC data, was 28-46%. Thus, the PRCs had a high ability to predict site effects of wind and assess the actual sampling situation. Comparison between protected and unprotected SPMDs showed that the sampler design reduced the wind-speed inside the devices and thereby the uptake and release rates

Sommer, S.G., McGinn, S.M., Hao, X., Larney, F.J., 2004. Techniques for measuring gas emissions from a composting stockpile of cattle manure. *Atmospheric Environment* 38 (28), 4643-4652.

Feedlot manure is a source of atmospheric ammonia (NH₃) carbon dioxide (CO₂) methane (CH₄) and nitrous oxide (N₂O), gases that are considered a risk to the environment. However, accurate estimates of emission of these gases from stockpiled manure are sparse due the lack of suitable measuring techniques. In our study, the integrated horizontal flux (IHF) and the backwards Lagrangian stochastic (bLS) dispersion micrometeorological techniques were adapted to measure gas emissions (NH₃, CH₄, N₂O and CO₂) from a manure pile. The results were compared with measurements using the static chamber technique. Net horizontal gas fluxes were determined by mounting passive NH₃ samplers, gas intakes for CO₂ and CH₄, and anemometers on poles that were always located up- and downwind of the pile as controlled by a wind vane. Further, NH₃ emission was estimated with the bLS technique using NH₃ concentration measured with a laser downwind of the pile. NH₃ emission measured with the IHF and bLS techniques were similar. Periodic measurements of emissions of CO₂ with the IHF technique by taking air samples with syringes and measuring CO₂ and CH₄ concentrations on a gas chromatograph, were similar to continuous measurements with the IHF technique measuring gas concentrations with an infrared gas monitor. Emissions of CO₂, CH₄ and N₂O measured with the static vented chamber technique were 12-22% of that measured with the IHF technique. Our results show that measurements of gas emission from stockpiled manure depend on the measuring technique and emphasizes the need for further validation of these techniques. (C) 2004 Elsevier Ltd. All rights reserved

Sorimachi, A., Sakamoto, K., Sakai, M., Ishihara, H., Fukuyama, T., Utiyama, M., Liu, H.J., Wang, W., Tang, D.G., Dong, X.H., Quan, H., 2004. Laboratory and field measurements of dry deposition of sulfur dioxide onto Chinese loess surfaces. *Environmental Science & Technology* 38 (12), 3396-3404 .

Laboratory and field measurements were conducted to examine dry deposition Of SO₂ onto Chinese loess surfaces using native soil sampled in the loess plateau, China. The field tests were employed in Beijing and Lanzhou, China, by directly measuring the dry deposition Of SO₂ on soil, which uses soil put on a collector as an SO₂ passive sampling medium. In the laboratory, a high rate of uptake to SO₂ deposition for Chinese soil surfaces due to the highly alkalinity was found. The uptake Of SO₂ deposition was dependent on the pH soil and relative humidity. Furthermore, we evaluated some factors that affect the measurement precision: response Of SO₂ uptake, repeatability, recovery factor, and variability associated with the weight and the surface coverage on the collectors. As a result, it was shown that the measurement precision was primarily related to the ratio of the SO₂ deposition amount relative to the sulfur content of the original soil. This result was consistent with the field observations. The laboratory and field results indicated an excellent agreement on the SO₂ uptake inherent in the results from the soil surfaces in different regions

Uchiyama, S., Aoyagi, S., Ando, M., 2004. Evaluation of a diffusive sampler for measurement of carbonyl compounds in air. *Atmospheric Environment* 38 (37), 6319-6326.

A diffusive sampling device (DSD-DNPH) has been developed for collection of ppb levels of 21 carbonyl compounds in indoor air. It is comprised of silica gel coated with 2,4-dinitrophenylhydrazine (DNPH) as the absorbent, a porous sintered polyethylene tube (PSP-diffusion filter) which acts as a diffusive membrane, and a small polypropylene syringe (PP-reservoir) which is used for the elution of the analytes from the absorbent. As the diffusive membrane comprises the entire cylindrical surface of the tube, it allows 'radial' exposure from all sides. A side-by-side comparison was made with active samplers, demonstrating good correlation (formaldehyde $r(2) = 0.992$). The sampling rate (71.9 ml min⁻¹) of formaldehyde was determined from comparison with an active sampling method and the sampling rates of other carbonyl compounds were calculated from their diffusion coefficients. These calculated sampling rates agreed with the experimental values. Little influence of wind velocity on the sampler was observed. The relative standard deviations for formaldehyde and acetaldehyde concentrations were 5.5% and 8.6%, respectively, with face velocity from 0 to 5.0 m/s. The DSD-DNPH enables the estimation of time-weighted average concentration of carbonyl compounds. Concentrations of formaldehyde estimated by the 7-day sampling method were nearly equal to the mean value calculated from the 24-hour sampling method measured over 7 days. This confirmed that the concentration of formaldehyde could be precisely monitored by 7-day continuous sampling. (C) 2004 Elsevier Ltd. All rights reserved

Urbat, M., Lehnendorff, E., Schwark, L., 2004. Biomonitoring of air quality in the Cologne conurbation using pine needles as a passive sampler - Part I: magnetic properties. *Atmospheric Environment* 38 (23), 3781-3792 .

High resolution temporal and spatial control of atmospheric pollutants is of crucial importance for environmental health monitoring. Passive sampling using natural vegetation biomonitoring allows acquisition of well-defined samples at affordable costs. We here present results from a study conducted in the conurbation of Cologne, Germany, based on airborne pollutants accumulated on pine needles. This integrated study includes (i) the microscopic analysis of pine needles and analysis of their magnetic properties, (ii) PAH, and (iii) selected trace elements (Fe, Cd, Pb, Ni, Cr, Cu). A major proportion of atmospheric pollutants is bound to particles, for which in part I of the study we present data on magnetic susceptibility, remanence measurements (IRM, ARM) and total Fe content. SEM-analysis indicates that particles accumulated on needles are mostly < 2.5 μm in diameter and comprise pollen or spores, mineral dust and silica-glassy or metallic spheroids. The latter were identified as magnetite with minor pyrrhotite. These particles derive from combustion of coal in power plants or fuels in vehicular engines. A close correlation of magnetic properties (susceptibility, SIRM, ARM) and Fe content shows that non-destructive, time-efficient enviromagnetics of needles serves as an excellent proxy for biomonitoring of combustion pollutants. Their spatial distribution within the conurbation of Cologne was determined for 43 locations integrated in a GIS-database. The dominant sources of fine metallic particulates (PM_{2.5}) are emissions from road traffic, including fuel combustion, corrosion and brake-wear and from railroad and tram traffic preferentially due to material wear. Parks, forests and agricultural areas show the lowest levels of pollution by magnetic particles, followed by residential areas. This implies that traffic emissions with short transportation distances (< 1.0 km) are dominant in the Cologne conurbation, whereas the contribution from power plants is negligible. (C) 2004 Elsevier Ltd. All rights reserved

van Pul, A., van Jaarsveld, H., Van Der Meulen, T., Velders, G., 2004. Ammonia concentrations in the Netherlands: spatially detailed measurements and model calculations. *Atmospheric Environment* 38 (24), 4045-4055.

From September 2000 to September 2001 the ammonia concentrations in air were measured on a monthly basis at 159 locations in the Netherlands using passive samplers. Eight of the locations were situated in the RIVM's National Air Quality Monitoring Network (LML), which have a continuous monitoring station. The yearly averaged concentrations of ammonia in the atmosphere in the Netherlands found from the passive samplers vary from 1 to 18 $\mu\text{g m}^{-3}$ and is on average 6.6 $\mu\text{g m}^{-3}$. Measurements taken at the eight LML stations represent the ammonia concentration level in the Netherlands reasonably well; the yearly average of ammonia concentrations at the LML stations is 18% higher than the average based on the passive sampler sites. The concentrations at the sites were calculated with the OPS model using ammonia emission inventories on 500- and 5000-m resolutions. The OPS model describes the spatial pattern well. The model calculations based on emissions at a 500-m resolution are more in agreement with the measurements than the calculations based on the emissions at a resolution of 5000 m. The reason for this is that at 500 m the sources are more exactly located than in the 5000-m inventory. The agreement increases if individual source locations within the 500-m grid cell are used. However, the OPS model based on the 500 m resolution emissions underestimates the measured concentrations by about 30%. The reason for this is not yet clear, but is most probably due to a combination of the uncertainties in emissions and the description of the dry deposition process in the model. The model comparison is discussed in terms of results of ammonia concentration modelling (with the OPS model) in other countries. (C) 2004 Elsevier Ltd. All rights reserved

Wilford, B.H., Harner, T., Zhu, J.P., Shoeib, M., Jones, K.C., 2004. Passive sampling survey of polybrominated diphenyl ether flame retardants in indoor and outdoor air in Ottawa, Canada: Implications for sources and exposure. *Environmental Science & Technology* 38 (20), 5312-5318.

The polybrominated diphenyl ethers (PBDEs) are widely used as flame retardants in plastics of soft furnishings, TV sets and computers, and insulation in the indoor environment. The penta-BDEs now banned in most parts of Europe but still used in North America are additive flame retardants that may be released to the indoor environment via volatilization or as dusts. In this study, to investigate general population PBDE exposure, air was sampled in 74 randomly selected homes in Ottawa, Canada and at seven outdoor sites during the winter of 2002-3, using polyurethane foam (PUF) disk passive air samplers. The passive sampling rate (2.5 $\text{m}^3 \text{day}^{-1}$) was determined through a pilot study employing active and passive samplers side-by-side at selected indoor locations. Indoor air concentrations of PBDEs were log-normally distributed with a geometric mean of 120 pg m^{-3} and a median of 100 pg m^{-3} , approximately 50 times higher than the range of outdoor air concentrations (<0.1-4.4 pg m^{-3}). The maximum daily human exposure via the inhalation pathway based on median PBDE levels found in this survey was estimated to be 1.9 ng day^{-1} (female) and 2.0 ng day^{-1} (male), representing 4.1% (f) and 4.4% (m) of overall daily intake

Angiuli, L., Bruno, P., Caputi, M., Caselli, M., de Gennaro, G., de Rienzo, M., 2003. Radical passive samplers for air quality monitoring in field comparison with a BTEX automatic analyser. Preliminary results. *Fresenius Environ. Bulletin* 12 (10), 1167-1172

Carmichael, G.R., Ferm, M., Thongboonchoo, N., Woo, J.H., Chan, L.Y., Murano, K., Viet, P.H., Mossberg, C., Bala, R., Boonjawat, J., Upatum, P., Mohan, M., Adhikary, S.P., Shrestha, A.B., Pienaar, J.J., et al., 2003. Measurements of sulfur

dioxide, ozone and ammonia concentrations in Asia, Africa, and South America using passive samplers. *Atmospheric Environment* 37 (9-10), 1293-1308

Cox, R.M., 2003. The use of passive sampling to monitor forest exposure to O₃, NO₂ and SO₂: a review and some case studies. *Environmental Pollution* 126 (3), 301-311.

The use of passive sampler systems is reviewed and discussed. These devices are able to determine both spatial and temporal differences in canopy exposure, as is demonstrated by their use in extensive monitoring of air-pollution exposure in forest health plots. Categorising forest health monitoring plots according to air-pollution exposure permits cause-effect analysis of certain forest health responses. In addition, passive sampling may identify areas affected by interaction between different gaseous pollutants. Passive samplers at the stand level can be used to resolve vertical profiles of ozone within the stand, and edge effects, which are important in exposure of understorey and ground flora. Recent case studies using passive samplers to determine forest exposure to gaseous pollutants indicate a potential for the development of spatial models on regional-, landscape-, and stand-level scales and the verification of atmospheric transport models. (C) 2003 Elsevier Ltd. All rights reserved

Fitz, D.R., Pisano, J.T., Malkina, I.L., Goorahoo, D., Krauter, C.F., 2003. A passive flux denuder for evaluating emissions of ammonia at a dairy farm. *Journal of the Air & Waste Management Association* 53 (8), 937-945.

Passive samplers have been shown to be an inexpensive alternative to direct sampling. Diffusion denuders have been developed to measure the concentration of species such as ammonia (NH₃), which is in equilibrium with particulate ammonium nitrate. Conventional denuder sampling has required active sampling that inherently requires air pumps and, therefore, electrical power. To estimate emissions of NH₃ from a fugitive source would require an array of active samplers and meteorological measurements to estimate the flux. A recently developed fabric denuder was configured in an open tube to passively sample NH₃ flux. Passive and active samplers were collocated at a dairy farm at the California State University, Fresno, Agricultural Research Facility. During this comparison study, NH₃ flux measurements were made at the dairy farm lagoon before and after the lagoon underwent acidification. Comparisons were made of the flux measurements obtained directly from the passive flux denuder and those calculated from an active filter pack sampler and wind velocity. The results show significant correlation between the two methods, although a correction factor needed to be applied to directly compare the two techniques. This passive sampling approach significantly reduces the cost and complexity of sampling and has the potential to economically develop a larger inventory base for ambient NH₃ emissions

Gilbert, N.L., Woodhouse, S., Stieb, D.M., Brook, J.R., 2003. Ambient nitrogen dioxide and distance from a major highway. *Science of the Total Environment* 312, 43-46

Isidori, M., Ferrara, M., Lavorgna, M., Nardelli, A., Parrella, A., 2003. In situ monitoring of urban air in southern Italy with the tradescantia micronucleus bioassay and semipermeable membrane devices (SPMDs). *Chemosphere* 52 (1), 121-126

Krupa, S., Nosal, M., Ferdinand, J.A., Stevenson, R.E., Skelly, J.M., 2003. A multi-variate statistical model integrating passive sampler and meteorology data to predict the frequency distributions of hourly ambient ozone (O₃) concentrations. *Environmental Pollution* 124 (1), 173-178

Roadman, M.J., Scudlark, J.R., Meisinger, J.J., Ullman, W.J., 2003. Validation of Ogawa passive samplers for the determination of gaseous ammonia concentrations in agricultural settings. *Atmospheric Environment* 37 (17), 2317-2325

Son, B., Breyse, P., Yang, W., 2003. Volatile organic compounds concentrations in residential indoor and outdoor and its personal exposure in Korea. *Environment International* 29 (1), 79-85.

To date, personal volatile organic compounds (VOCs) exposure and residential indoor and outdoor VOCs levels have not been characterized in Korea. In this study, residential indoor and outdoor VOCs concentrations were measured and compared simultaneously with the personal exposure for each of 30 participants in a medium city, Asan, and in a metropolitan city, Seoul. Factors that influence personal VOCs exposures were assessed in relation to house characteristics and time activity information. All VOC concentrations were measured using passive samplers during a 24-h period and analyzed using GC-MS. Ten target VOCs were benzene, trichloroethylene, toluene, o-xylene, p-xylene, ethylbenzene, MIBK, n-octane, styrene, and 1,2-dichlorobenzene. Residential indoor and outdoor VOCs concentrations measured in Seoul were significantly higher than those in Asan. Indoor/outdoor (I/O) ratios for all target compounds ranged from 0.94 to 1.51 and I/O ratios of Asan were a little higher than those of Seoul. Results indicate that time activity information can be used to predict personal exposures, although such predictions will result in an over estimation

compared to measured exposures. Factors which influence the indoor VOCs level and its personal exposure in relation to house characteristics included house age, indoor smoking, and house type. (C) 2002 Elsevier Science Ltd. All rights reserved

Wagner, J., Macher, J.M., 2003. Comparison of a passive aerosol sampler to size-selective pump samplers in indoor environments. *AIHA Journal* 64 (5), 630-639.

The objective of this work was to investigate the ability of the Wagner-Leith passive aerosol sampler to measure indoor exposures over periods of 24 hours to 2 weeks. An automated analysis technique was developed so that lower aerosol concentrations could be sampled over shorter time periods. A test of the new analytical method against a manual method showed good agreement. The passive sampler was tested alongside three pump-operated, size-selective samplers in indoor environments. Generally, good correlation with the active samplers was observed. Correlation with a personal impactor with uncoated substrates was not statistically significant, but the cyclone, MS&T impactor, and overall correlations had R-2 values of 0.73-0.88. Combining these data with a previous study produced an R-2 of 0.96 between passive and active results. Large discrepancies (up to 147%) between passive and personal impactor results were observed and were attributed to particle bounce in the impactor, passive sampler imprecision due to few collected fine particles, and problems with detection of organic particles in the passive sampler. The Wagner-Leith sampler has now been tested over five orders of magnitude in mass concentration, in which it has proved useful for obtaining aerosol size distributions, mass fractions, qualitative elemental analysis, and morphology of individual particles. The sampler has several limitations, including increased sensitivity to contamination when fewer particles are collected, uncertainties in sampling semi-volatile particles, and the need for some expertise and expense to analyze the passive samples

Eisner, A.D., Heist, D.K., Drake, Z.E., Mitchell, W.J., Wiener, R.W., 2002. On the impact of the human (child) microclimate on passive aerosol monitor performance. *Aerosol Science & Technology* 36 (7), 803-813, UYUAY6PGNEDAB1YCBQY.

Research into the wind microclimate and its effect on the accuracy and effectiveness of passive aerosol monitors is expanding as the importance of personal monitoring versus regional monitoring increases. The important phenomena for investigation include thermal and dynamic effects of the human body, contaminant dispersion around a human body and within a building complex, and the wind environment within a building (indoor/outdoor) complex. This paper demonstrates that the microclimate around the human body plays a critical role in contaminant transport near the body and thus can affect particle concentration measurements by personal samplers.

EN 13528-2, 2002. Ambient air quality - Diffusive samplers for the determination of concentrations of gases and vapours - Requirements and test methods Part 2: Specific requirements.

Ryan, T.J., Hart, E.M., Kappler, L.L., 2002. VOC exposures in a mixed-use university art building. *AIHA Journal* 63 (6), 703-708.

Despite a sizable educational art enterprise in the United States there is a dearth of rigorously performed studies of exposures to persons engaged in such activities. Exposures to 45 EPA-designated volatile organic compounds were examined in printmakers in a mixed-use university art school served by a 100% exhausted mechanical ventilation system. Personal exposures (n=90) were compared with area concentrations (n=36) in the studio area and at a second location at the same facility. For personal exposure assessments a cohort of 12 students wore passive dosimeters twice weekly over a 6-week period. Numerous compounds were found, the most prevalent being toluene at an average concentration of 64.6 µg/m³ (17.1 ppb; range <1-319 ppb); 1,1,1, trichloroethane at 40.5 µg/m³ (7.5 ppb; range <11-211 ppb); xylenes at 8.0 µg/m³ (1.8 ppb; range <1-43 ppb); 1,3,5-trimethyl benzene at 6.2 µg/m³ (1.3 ppb; range <.3-32 ppb); propyl benzene at 5.0 µg/m³ (1.0 ppb; range <.5-27 ppb); methylene chloride at 4.9 µg/m³ (1.4 ppb; range <1-10 ppb); and ethyl benzene at 4.5 µg/m³ (1.1 ppb; range <.4-23 ppb). Personal exposures were considerably higher than average area air concentrations, with the exception of methylene chloride concentrations, which were five times higher at the print cleaning operation. Floors where solvents were not used had no detectable exposures (typical lower limit of detection 1 ppb) and were free of solvent odors. Despite frequent solvent contact with skin, personal protective equipment was seldom used. Results indicate that in mixed-use facilities such as this, nonrecirculating general ventilation systems can effectively eliminate indoor air quality issues between floors, despite perceptible odors on solvent use floors. For total exposure assessments in such processes, contact exposures from printmaking solvents during cleaning procedures are a potentially important consideration

Saunders, F., Larson, L., Tatum, V., 2002. Evaluation of passive card monitors for hydrogen sulfide for use in kraft pulp mill workplace atmospheres. *AIHA Journal* 63 (3), 317-325.

Six different brands of passive card monitors representing three different types of card monitor were evaluated for their effectiveness in testing for hydrogen sulfide in workplace atmospheres. The cards were evaluated both in the laboratory and in a kraft pulp mill according to a protocol that closely follows that recommended by the National Institute for Occupational Safety and Health and other researchers for passive samplers. The performances of the Envirometrics Air-Chem Technologies and the Gilian ChemAir quantitative cards, the Gilian ChromAir and VICI Metronics Colortec semiquantitative cards, and the American Gas & Chemical Co. Leak-Tec and Gilian SafeAir indicator cards were evaluated. The detection limits of the cards were determined, and the cards were exposed to a range of hydrogen sulfide concentrations (1, 5, 10, 20 ppm), face velocities (0, 50 ft/min), and temperature/humidity combinations (95degreesF/90% humidity, 77degreesF/50% humidity, 40degreesF/20% humidity). The cards' responses to short-term and variable concentration exposures as well as to the potential interferents methyl mercaptan, dimethyl sulfide, dimethyl disulfide, sulfur dioxide, and carbon monoxide were assessed. Each of the cards tested demonstrated a usefulness for the detection and/or quantification of hydrogen sulfide at concentrations and under conditions relevant to kraft pulp mill workplace atmospheres. Which card is best depends on the application, sampling conditions, and level of confidence necessary in the results. The Gilian ChemAir quantitative card performed well under most conditions with acceptable accuracy (13% lab, 26% field), and no response to potential interferents or to changes in face velocity, temperature, and humidity. The Envirometrics ACT quantitative cards did not perform as well, with an accuracy level of only 46% in the lab. They also seemed to be more affected by changes in face velocity, temperature, and humidity. Both semiquantitative cards (Gillian ChromAir, VICI Metronics Colortec) provided reasonable approximations of hydrogen sulfide levels in the range of the hydrogen sulfide occupational exposure levels although the VICI card had a much lower detection limit. Neither performed well at high temperature and humidity. The response of VICI card was more affected by changes in face velocity, whereas the Gilian ChromAir showed some response to reduced sulfur gas interferents. Both indicator cards (Leak-Tec, Gilian SafeAir) performed well, responding to 20 ppm hydrogen sulfide within 1 min and to 5 ppm within 5 min. Neither was significantly affected by extremes of temperature and humidity

Shoeib, M., Harner, T., 2002. Characterization and comparison of three passive air samplers for persistent organic pollutants. *Environmental Science & Technology* 36 (19), 4142-4251.

The accumulation of persistent organic pollutants by three passive sampling media - semipermeable membrane devices (SPMDs), polyurethane foam (PUF) disks, and an organic-rich soil - was investigated. The media were exposed to contaminated indoor air over a period of 450 days, and concentrations in the air and in the media were monitored for individual polychlorinated biphenyl (PCB) congeners and polychlorinated naphthalene homologue groups. Uptake was initially linear and governed by the surface area of the sampler and the boundary layer air-side mass transfer coefficient (MTC). Mean values of the MTC were 0.13, 0.11, and 0.26 cm s⁻¹ for SPMD, PUF and soil, respectively. As the study progressed, equilibrium was established between ambient air and the passive sampling media for the lower molecular weight PCB congeners. This information was used to calculate passive sampler - air partition coefficient, and the resulting regressions were used to predict K_{PSM-A} . These were correlated to the octanol-air partition coefficient, and the resulting regressions were used to predict K_{PSM-A} for the full suite of PCBs. Information on MTC, K_{PSM-A} , surface area, and effective thickness of each sampler was used to estimate times to equilibrium for each medium. These ranged from tens of days for the lower molecular weight congeners to tens of years for the higher molecular weight PCBs. Expressions were also developed to relate the amount of chemical accumulated by the passive sampling media to average ambient air concentrations of the integration period of the sample.

Smith, P.A., Kluchinsky, T.A., Savage, P.B., Erickson, R.P., Lee, A.P., Williams, K., Stevens, M., Thomas, R.J., 2002. Traditional sampling with laboratory analysis and solid phase microextraction sampling with field gas chromatography/mass spectrometry by military industrial hygienists. *AIHA Journal* 63 (3), 284-292.

The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the United States Department of Defense or the Uniformed Services University of the Health Sciences. Rapid on-site detection and identification of environmental contaminants to which personnel may be exposed is often needed during military deployment situations. The availability of military industrial hygienists with capabilities for "complete" on-site exposure assessment of chemical species should allow detection and identification of a number of important stressors almost immediately following sample collection. Portable gas chromatography/mass spectrometry (GC/MS) provides a rapid and efficient separation of volatile and semivolatile organic analytes, accompanied by sensitive electron impact ionization-mass spectrometry (EI-MS) detection. The use of GC/MS in the field is limited, however, by equipment cost, complexity of the equipment, and the analytical process. Additionally, a skilled operator is needed to obtain useful separations and to interpret mass spectral data. To demonstrate benefits and limitations of "complete" exposure assessment capabilities, a previously unidentified complex mixture, produced by thermal dispersion of riot control agents, was examined. Established active sampling methods were used with laboratory analyses. Solid phase microextraction, a passive sampling method that simplifies preparation for GC/MS analysis, also was used with a field-portable

GC/MS system. Both sampling/analysis methods were used to detect CS riot control agent-derived air contaminants dispersed from riot control type canisters through oxidizer-supported combustion of a chemical fuel

Caputi, M. (2001) Caratterizzazione dei composti organici volatili nell'atmosfera mediante campionatori passivi e desorbimento termico. Thesis. University of Bari, Dept. of Chemistry,.

Hamonangan, E., Kondo, A., Kaga, A., Inoue, Y., Soda, S., Yamaguchi, K., 2001. Monitoring of sulfur dioxide, nitrogen dioxide, and nitrogen oxide by passive sampler in the Jakarta metropolitan area. Proceedings, 12th World Clean Air & Environment Congress and Exhibition: Greening the New Millennium. International Union of Air Pollution Prevention and Environmental Protection Associations, Seoul, Korea

Liu, L.J.S., Dills, R.L., Paulsen, M., Kalman, D.A., 2001. Evaluation of media and derivatization chemistry for six aldehydes in a passive sampler. Environmental Science & Technology 35 (11), 2301-2308.

We evaluated the GMD passive sampler for its suitability to measure six aldehydes over a 7-d period in population exposure studies. The six target aldehydes were formaldehyde, acetaldehyde, acrolein, crotonaldehyde, glyoxal, and methylglyoxal. The GMD sampler contains a silica gel-impregnated cellulose pad coated with 2,4-dinitrophenylhydrazine (DNPH) hydrochloride. This agent reacts with formaldehyde to form a hydrazone that is quantified with a high-performance liquid chromatograph. The GMD sampler was tested for background contamination and aldehyde recoveries after 0, 1, and 7 d of storage. Results indicated that the GMD monitor, as currently manufactured, is suitable for shorter-term sampling (up to 24 h) of formaldehyde and acetaldehyde. It is however not acceptable for sampling of acetaldehyde, acrolein, crotonaldehyde, glyoxal, and methylglyoxal over a 7-d exposure period due to the chemical reactions on the silica gel-impregnated cellulose pad. Glyoxal - and methylglyoxal - DNPH derivatives formed on the cellulose and Teflon-coated glass fiber pads that had been prepared with glycerol under acidic and oxidative conditions. Acrolein - and crotonaldehyde - DNPH derivatives diminish through the reverse reaction of the DNPH derivatives to form free aldehydes under acidic conditions. We showed that the unknown reaction products of acrolein and crotonaldehyde derivatives were not pyrazolines but probably resulted from *E/Z* isomerization. These conversion reactions are favored in acidic conditions present in either the derivatization solution or the collection medium. The most consistent recovery was obtained on glass fiber pads. In particular, recoveries of crotonaldehyde - and acrolein - DNPH derivatives were increased through the use of a pH 4 buffered derivatization solution. These chemical instability problems were overcome by using a pH 4 buffer (citric acid/sodium citrate) and an alternative hygroscopic agent (1,3-butanediol) in the DNPH derivatization solution. Results with DNPH derivatives from these spiking experiments were further confirmed with gas-phase spiking experiments. We determined the optimal acidity, buffer solution, and concentrations of the buffer solution and 1,3-butanediol for the DNPH derivatization solution. This new formulation of the DNPH derivatization solution can be used for collection of the six target aldehydes over a 7-d sampling period.

Lohmann, R., Corrigan, B.P., Howsam, M., Jones, K.C., Ockenden, W.A., 2001. Further developments in the use of semipermeable membrane devices (SPMDs) as passive air samplers for persistent organic pollutants: Field application in a spatial survey of PCDD/Fs and PAHs. Environmental Science & Technology 35 (12), 2576-2582.

Semipermeable membrane devices (SPMDs) were deployed at 19 sites in northwest England to test their efficacy as passive atmospheric samplers for polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs) and polycyclic aromatic hydrocarbons (PAHs). SPMDs were found to be efficient samplers for vapor phase species in the atmosphere, with good reproducibility between samplers. Species which are partially or completely particle associated under ambient U.K. conditions were also sampled by the SPMDs but with poorer reproducibility. It is suggested that SPMDs could be used to indicate "hot-spots" of particulate associated species, however. Differences in absolute and relative concentrations of all PCDD/Fs and PAHs sequestered by the SPMDs were observed between sites. High amounts were sequestered in SPMDs at sites where previous active monitoring has indicated relatively high atmospheric concentrations, confirming the potential of SPMDs as a tool for semiquantitative spatial monitoring of atmospheric species. SPMDs also respond to differences in the mixture of compounds present in the atmosphere, thereby aiding source apportionment studies.

Palassis, J., Bryant, J., Zey, J.N., 2001. Detector tubes, direct-reading passive badges, and dosimeter tubes. In *Air Sampling Instruments for Evaluation of Atmospheric contaminants*, 9th Edition, Cohen, B.S., McCammon, C.S.J., editors. ACGIH, Cincinnati, OH, pp. 457-506

Rabaud, N.E., James, T.A., Ashbaugh, L.L., Flocchini, R.G., 2001. A passive sampler for the determination of airborne ammonia concentrations near large-scale animal facilities. Environmental Science & Technology 35 (6), 1190-1196.

Few data are available on the ammonia emissions of large-scale outdoor animal facilities in arid climates such as those found in California's San Joaquin Valley. Passive samplers provide an ideal tool for studying such large and heterogeneous area sources, because they are inexpensive, portable, and fully self-contained. UC Davis passive ammonia samplers incorporate modifications on a previous design, the Willems Badge, for ease of analysis. Citric acid was chosen as a coating medium though it performed as well as oxalic, sulfuric, and tartaric acids. Zeflur PTFE prefilters were used instead of Teflo though both showed the same resistance to diffusion. Citric acid-coated filters were stable for up to 10 weeks, though more so if stored in Petri dishes rather than in the sampling cassettes themselves. The most effective sampler position was found to be in a face-down configuration fixed into the wind to avoid debris and sensitivity to wind shifts. A new method of rinsing the filters within the cassettes by dropwise elution proved highly effective, with 85% of the ammonium being removed in the first 3 mL of the 10-mL rinse volume. Application of the sampler at a dairy in the Joaquin Valley revealed large variations in concentrations at different locations along the downwind fenceline, which correlated with animal populations and activities directly upwind. In addition, large variations in ammonia concentrations were observed in relation to time of day and animal activity. Field blank loadings were of 1.40 mug NH₄-N/filter (SD = 0.74 mug NH₄-N/filter). Replicate passive samplers placed side-by-side during sampling episodes agreed with a slope of 1.010 (standard error = 0.028). Impingers were used as a reference method to obtain the correlation between filter loadings and air concentrations, yielding an "effective sampling rate" for the passive samplers of 6.18 L/h (error = 0.23 L/h) Using a theoretical calculation that "effective flow rate" was calculated to be 6.29 L/h. The method's limit of detection was found to be 82.5 mug NH₄- N/m(3). Wind speed was found to theoretically affect linearity of sampler response only for speeds less than 0.92 m/s

Sather, M.E., Varns, J.L., Mulik, J.D., Glen, G., Smith, L., Stallings, C., 2001. Passive ozone network of Dallas: A modeling opportunity with community involvement. *Environmental Science & Technology* 35 (22), 4426-4435.

Attaining the current lower tropospheric U.S. ozone standards continues to be a difficult task for many areas in the U.S. Concentrations of ozone above the standards negatively affects human health, agricultural crops, forests, and other ecosystem elements. This paper describes year two (1999) of a regional networking of passive and continuous ozone monitoring sites in the Dallas-Fort Worth (DFW) Metroplex region. The objectives of the second year of study were to (1) validate conclusions of the 1998 Passive Ozone Network of Dallas (POND) I study, (2) define the value of taking 12-h diurnal samples in addition to 24-h samples, and (3) add to the scientific knowledge base of rural/urban ozone comparison studies. Results of the POND II (1888) study demonstrated that ozone concentrations exceeding the new 8-h ozone standard could be recorded at least 130 km, or 80 miles, from the DFW Metroplex core in more rural areas. In addition, results of the POND II study indicated that ozone concentrations exceeding the 8-h standard probably occurred in areas recording a 12-h daytime ozone concentration above 60 parts per billion (ppb). The 12-h passive ozone data from POND II also suggests the relative magnitude of anthropogenic pollution influence could be assessed for rural passive ozone sites. The data from the POND II study provide modelers a rich database for future photochemical subgrid development for the DFW ozone nonattainment area. Indeed, the POND database provides a great amount of additional ozone ambient data covering 26 8-h and 13 1-h ozone standard exceedance days over an approximate 25,000 km² region. These data should help decrease uncertainties derived from future DFW ozone model exercises.

Skelly, J.M., Ferdinand, J.A., Savage, J.E., Jagodzinski, J.M., Mulik, J.D., 2001. A 13-week comparison of passive and continuous ozone monitors at forested sites in north-central Pennsylvania. *Journal of the Air & Waste Management Association* 51 (9), 1280-1287

Tolnai, B., Gelencserb, A., Hlavay, J., 2001. Theoretical approach to non-constant uptake rates for tube-type diffusive samplers. *Talanta* 54 (4), 703-713

Vainiotalo, S., Vaaranrinta, R., Tornaesus, J., Aremo, N., Hase, T., Peltonen, K., 2001. Passive monitoring method for 3-ethenylpyridine: A marker for environmental tobacco smoke. *Environmental Science & Technology* 35 (9), 1818-1822.

A new method was developed to assess environmental tobacco smoke in air. The method is based on passive sampling and subsequent measurement of the concentration of 3-ethenylpyridine, a vapor-phase compound specific to tobacco smoke. Air samples were collected using a 3M organic vapor monitor. Tests were carried out in a dynamic chamber to determine the sampling rate (25.7 cm³/min). 3-Ethenylpyridine was desorbed from the sampler with 1 mL of pyridine/toluene mixture. 3-Ethenylpyridine was quantified by gas chromatography/mass spectrometry. The limit of detection was 0.01 µg/sample, corresponding to a concentration of 0.27 µg/m³ air calculated for a sampling period of 24 h. Field measurements were carried out to test the performance of the method. Mean concentrations ranging from 1.3 to 5.3 µg/m³ were measured for 3-ethenylpyridine in smoking environments, but no 3-ethenylpyridine was detected in nonsmoking environments. Active sampling using charcoal tubes was used as a reference method in the chamber tests and field measurements. Individual exposures can be easily and accurately measured by means of the passive

sampler. Because of simple sample treatment, the method is also well-suited for large-scale monitoring of environmental tobacco smoke.

Varns, J.L., Mulik, J.D., Sather, M.E., Glen, G., Smith, L., Stallings, C., 2001. Passive ozone network of Dallas: A modeling opportunity with community involvement. 1. Environmental Science & Technology 35 (5), 845-855.

Despite tremendous efforts toward regulating and controlling tropospheric ozone (O_3) formation, a large portion of the U.S. population presently lives in environments where air quality exceeds both 1- and 8-h National Ambient Air Quality Standards (NAAQS) set for O_3 . High O_3 concentrations annually cost the United States billions of dollars in excessive human health costs, reduced crop yields, and ecological damage. This paper describes a regional networking of O_3 monitoring sites, operated by the public, that used simplified passive sampling devices (PSDs). In collaboration with EPA Region 6, a lay network (i.e., *Passive Ozone Network of Dallas*, acronym POND), consisting of 30 PSD sites in the Dallas-Fort Worth (DFW) Metroplex, a region representing 16 counties, successfully measured daily ozone during 8 weeks of the 1998 high ozone season. It was demonstrated that the concerned public, when properly trained, could successfully operate a large PSD network that requires daily sample handling and weekly mailing procedures, even from remote sites. Data treatment of the 2880 POND measurements included (i) high correlations with collocated continuous monitoring data [r range = 0.95 - 0.97], (ii) daily O_3 contour mapping of the 24,000 km² area, and (iii) a ranking of O_3 severity in 12 peri-urban counties for guidance in siting additional monitors. With a new 8-h NAAQS standard now in place, a cost-effective network such as POND could aid regional airshed models in generating meaningful guidance for O_3 state implementation plans (SIPs) by providing input that is representative of both rural and urban sites.

Wagner, J., Leith, D., 2001. Passive aerosol sampler Part I. Principle of operation. Aerosol Science & Technology 34 (2), 186-192.

A method has been developed to estimate average concentrations and size distributions with a miniature passive aerosol sampler. To use the passive sampler, one exposes it to an environment for a period of hours to weeks. The passive sampler is intended to monitor ambient, indoor, or occupational aerosols and has potential utility as a personal sampler. The sampler is inexpensive and easy to operate and is capable of taking long-term samples to investigate chronic exposures. After sampling, the passive sampler is covered and brought to the lab. Scanning electron microscopy (SEM) and automated image analysis are used to count and size collected particles with $d_p > 0.1 \mu\text{m}$. Alternatively, more advanced microscopy techniques can be used for ambient-pressure analysis or elemental characterization. Image analysis is used in conjunction with particle density and shape factors to obtain the mass flux as a function of aerodynamic diameter. The flux and a deposition velocity model are then used to estimate the average mass concentration and size distribution over the sampling period. The deposition velocity model consists of a theoretical component and an empirical component. The theoretical component incorporates gravitational, inertial, and diffusive mechanisms, but can be approximated by the simple terminal settling velocity in many cases. This article, Part I, describes how measurements are made with the passive sampler. The sampler design, theoretical component of the deposition velocity model, and microscopy methods are presented. Part II describes wind tunnel experiments performed to measure sampler precision and determine the empirical component of the deposition velocity.

Wagner, J., Leith, D., 2001. Field tests of a passive aerosol sampler. Journal of Aerosol Science 32 (1), 33-48.

Field tests have been conducted to evaluate the passive aerosol sampler described by Wagner and Leith (2000a,b) *Aerosol Science Technology*, in press). Tests were conducted in a well-ventilated occupational environment with coarse, high-concentration aerosols. Measured friction velocities were less than 0.4 m s^{-1} , a range in which passive sampler performance does not depend on turbulence. Passive sampler results correlated well with those of eight-stage cascade impactors, with $R^2 = 0.80$ and 0.93 for $\text{PM}_{2.5}$ and PM_{10} , respectively.

Average disagreement between the passive samplers and the impactors was -31 and 41% for $\text{PM}_{2.5}$ and PM_{10} , respectively. These discrepancies were attributed to the small amount of fine particles present, hygroscopic particles, and particle bounce in the impactors. The average CV PM_{10} for all samples was 20%. The average CV $\text{PM}_{2.5}$ for hygroscopic samples was much higher, 59% water losses in the samples created ill-defined particle boundaries which led to imprecision.

Wagner, J., Leith, D., 2001. Passive aerosol sampler Part II. Wind tunnel experiments. Aerosol Science & Technology 34 (2), 193-201.

Wind tunnel experiments have been performed on a passive aerosol sampler. The sampler estimates average concentrations and size distributions using a deposition velocity model and the measured particle flux to the sampler. The small-scale wind tunnel incorporated a high-output aerosol generator that produced nonvolatile, polydisperse particles. An eight-stage impactor was connected to the tunnel with an isoaxial, isokinetic probe and was equipped with polycarbonate-membrane substrates saturated with oleic acid to minimize particle bounce. Before performing experiments, the tunnel's test section was characterized. Aerosol concentrations were determined to have a CV < 6%. The friction velocity, an index of turbulence, was found to range from 0.09 to

0.25 m/s for wind speeds of 1.5 to 5 m/s. The empirical portion of the deposition velocity model, γ_m , was determined as a function of particle size by minimizing the sum-of-squares difference between impactor and passive sampler across all size bins and all experiments. The relatively simple correlation is a function of the particle Reynolds number only. Precision was assessed by running three passive samplers simultaneously in each experiment. The tests yielded CVPM2.5 = 18.1% and CVPM10 = 32.2%. ANOVA tests were conducted on accuracy and precision to see whether they depended on wind speed, relative humidity, or aerosol concentration, and accuracy was tested with respect to particle size. No significant trends were observed. Sensitivity analysis showed that the volume shape factor is the most important of the mass and shape conversion factors. If SEM is used, the passive sampler will exhibit some error when sampling volatile aerosols. Because concentrations fluctuate over time, long-term exposures measured by the passive sampler should be more accurate than conventional averages based on short-term samples.

Bertoni, G., Tappa, R., Allegrini, I., 2000. Assessment of a new passive device for monitoring benzene and other volatile aromatic compounds in the atmosphere. *Annali di Chimica* 90, 249-263

Brumbaugh, W.G., Petty, J.D., May, T.W., Huckins, J.N., 2000. A passive integrative sampler for mercury vapor in air and neutral mercury species in water. *Chemosphere - Global Change Science* 2 (1), 1-9

Gillett, R.W., Kreibich, H., Ayers, G.P., 2000. Measurement of indoor formaldehyde concentrations with a passive sampler. *Environmental Science & Technology* 34 (10), 2051-2056.

An existing Ferm type passive sampler technique has been further developed to measure concentrations of formaldehyde gas in indoor air. Formaldehyde forms a derivative after reaction with a filter coated with 2,4-dinitrophenylhydrazine (2,4-DNPH). The formaldehyde 2,4-dinitrophenylhydrazine derivative (formaldehyde-2,4-DNPH) is extracted from the filter, and the concentration is determined by high performance liquid chromatography. The technique has been validated against an active sampling method, and the agreement is close when the appropriate laminar boundary layer depth is applied to the passive measurement. For this technique an exposure period of 3 days is equivalent to a limit of detection of formaldehyde of 3.4 bpbv and a limit of quantification of 7.6 ppbv. To test the performance of the passive samplers ambient formaldehyde measurements were carried out inside homes and in a range of workplace environments.

Kreibich, G.H., Ayers, G.P., 2000. Measurement of indoor formaldehyde concentrations with a passive sampler. *Environmental Science & Technology* 34 (10), 2051-2056

Krupa, S.V., Legge, A.H., 2000. Passive sampling of ambient, gaseous air pollutants: An assessment from an ecological perspective. *Environmental Pollution* 107, 31-45

Muller, J.F., Hawker, D.W., Connell, D.W., Komp, P., McLachlan, M.S., 2000. Passive sampling of atmospheric SOCs using tristearin-coated fiberglass sheets. *Atmospheric Environment* 34 (21), 3525-3534

Quintana, P.J.E., Samimi, B.S., Kleinman, M.T., Liu, L.J., Soto, K., Warner, G.Y., Bufalino, C., Valencia, J., Francis, D., Hovell, M.H., Delfino, R.J., 2000. Evaluation of a real-time passive personal particle monitor in fixed site residential indoor and ambient measurements. *Journal of Exposure Analysis and Environmental Epidemiology* 10 (5), 437-445

Ballach, J., Greuter, B., Schultz, E., Jaeschke, W., 1999. Variations of uptake rates in benzene diffusive sampling as a function of ambient conditions. *Science of the Total Environment* 243/244, 203-217

Bernard, N.L., Gerber, M.J., Astre, C.M., Saintot, M.J., 1999. Ozone measurement with passive samplers: Validation and use for ozone pollution assessment in Montpellier, France. *Environmental Science & Technology* 33 (2), 217-222.

The objective of this pilot study was to determine a way of assessing personal exposure to ozone (O₃) for use in a study of O₃ effects on health. Passive samplers (Passam, AG) were used to measure pollution levels in Montpellier, France. They were standardized using an O₃ analyzer. Blanks and duplicates were tested to evaluate sensitivity (6.6 µg/m³) and imprecision (2µg/m³). They were validated by comparing on-site measurements with those of the automatic UV absorption analyzers of the regional air quality network (AMPADI-LR). The correlation coefficient was $r = 0.9$, $p < 10^{-3}$, and the regression coefficient was close to 1. The on-site measurements provided information about local pollution. Distance from NO₂ sources (urban traffic) and sunlight intensity were identified as environmental determinants of O₃ pollution. Residential microenvironmental concentrations and personal exposure were measured for 110 subjects. The indoor/outdoor ratio is higher than in Mexico City and higher than Toronto in summer but comparable

with that in Toronto in winter. The relationship between personal exposure and indoor home measurements is closer than that between personal exposure and outdoor home environment measurements. This is especially true for the spring and summer months, when the correlation between indoor and outdoor measurements is low ($r = 0.23$, $p < 0.05$). At the workplace, on the other hand, there is a close correlation between indoor and outdoor ozone measurements in summer ($r = 0.80$, $p < 0.001$), as there is between personal exposure and outdoor measurements ($r = 0.60$, $p < 0.001$).

Brown, R.H., Wright, M.D., Plant, N.T., 1999. The use of diffusive sampling for monitoring of benzene, toluene and xylene in ambient air. Pure & Applied Chemistry 71 (10), 1993-2008

Chung, C.W., Morandi, M.T., Stock, T.H., Afshar, M., 1999. Evaluation of a passive sampler for volatile organic compounds at ppb concentrations, varying temperatures, and humidities with 24-h exposures 2. Sampler performance. Environmental Science & Technology 33 (20), 3666-3671.

The performance of the 3M 3520 organic vapor monitor (OVM) as a tool for monitoring inhalation exposures to volatile organic compounds (VOCs) in nonoccupational community environments was evaluated by using combined controlled test atmospheres of benzene, 1,3-butadiene, carbon tetrachloride, chloroform, 1,4-dichlorobenzene, methylene chloride, styrene, tetrachloroethylene, and toluene. Eight OVMs were simultaneously exposed to concentrations of 10, 20 and 200 $\mu\text{g}/\text{m}^3$ in combination with temperatures of 10, 25 and 40 °C and relative humidities of 12, 50, and 90% for 24 h. The results of this study indicate that the performance of the 3520 OVM is compound-specific and depends on concentration, temperature, and humidity. With the exception of 1,3-butadiene under most conditions and styrene and methylene chloride at very high relative humidities, recoveries showed a negative bias as compared to calculated chamber concentrations but were generally within $\pm 25\%$ of theory, indicating that the 3520 OVM can be effectively used over the range of concentrations and environmental conditions tested with a 24-h sampling period. Increasing humidities resulted in increasing negative bias from full recovery. Reverse diffusion experiments conducted at 200 $\mu\text{g}/\text{m}^3$ and five temperature/humidity combinations indicated diffusion losses only for 1,3-butadiene, methylene chloride, and styrene under increased humidity conditions. The recovery rates reported in this study can be used for estimating measurement biases when using OVMs for indoor, outdoor, and personal air monitoring of VOCs in community environments.

Hansen, B., Wyers, G.P., Nornberg, P., Nemitz, E., Sutton, M.A., 1999. Intercalibration of a passive wind-vane flux sampler against a continuous-flow denuder for the measurements of atmospheric ammonia concentrations and surface exchange fluxes. Atmospheric Environment 33 (27), 4379-4388

Heal, M.R., O'Donoghue, M.A., Cape, J.N., 1999. Overestimation of urban nitrogen dioxide by passive diffusion tubes: A comparative exposure and model study. Atmospheric Environment 33 (4), 513-524

Kato, S., Yuan, P.F., Xian, W.B., Shan, C.J., Kiatabatake, M., Yamauchi, T., 1999. Low temperature SO₂ sampling by passive samplers in a northeastern Chinese industrialized area. J. Environ. Sci. Health A34 (2), 371-390

Norris, G., Larson, T., 1999. Spatial and temporal measurements of NO₂ in an urban area using continuous mobile monitoring and passive samplers. Journal of Exposure Analysis and Environmental Epidemiology 9 (6), 586-593

Ayers, G.P., Keywood, M.D., Gillett, R., Manins, P.C., Malfroy, H., Bardsley, T., 1998. Validation of passive diffusion samplers for SO₂ and NO₂. Atmospheric Environment 32 (20), 3586-3592

Brown, R.C., Thorpe, A., Hemingway, M.A., 1998. A passive sampler for monitoring urban particulate: Preliminary results. Environmental Monitoring and Assessment 52 (1-2), 19-28

Brown, V.M., Crump, D.R., 1998. Diffusive sampling of volatile organic compounds in ambient air. Environmental Monitoring and Assessment 52 (1-2), 43-55

Van Reeuwijk, H., Fischer, P.H., Harssema, H., Briggs, D.J., 1998. Field comparison of two NO₂ passive samplers to assess spatial variation. Environmental Monitoring and Assessment 50 (1), 37-51

Wright, M.D., Plant, N.T., Brown, R.H., 1998. Diffusive sampling of VOCs as an aid to monitoring urban air quality. Environmental Monitoring and Assessment 52 (1-2), 57-64

Gibson, L.T., Cooksey, B.G., Littlejohn, D., Tennent, N.H., 1997. Determination of experimental diffusion coefficients of acetic acid and formic acid vapours in air using a passive sampler. *Analytica Chimica Acta* 341, 1-10

Shooter, D., Brimblecombe, P., Shooter, J., Lowe, D., Day, P.J., Du, S., 1997. Some characteristics and applications of nitrogen dioxide passive samplers. *Environmental Technology* 18 (3), 243-254.

Ion chromatography has been used to measure nitrite (NO₂⁻) and nitrate (NO₃⁻) concentrations in the aqueous extracts from exposed and blank (unopened) passive samplers designed for the measurement of atmospheric nitrogen dioxide (NO₂). Concentrations of NO₂ increased on storage of both opened and unopened samplers, however NO₃⁻ concentrations were dependent on sampler cleaning and preparation. Only extract NO₂⁻ concentrations were needed to calculate atmospheric NO₂ levels when using the samplers for monitoring. Analytical methods for passive samplers extracts have been compared in the laboratory with good agreement being found. Calculations of possible background contamination levels suggest that sampler results may be influenced by the solubility of NO₂ in the plastic construction materials but not by permeation of NO₂ through the sampler walls. Passive samplers have been used to measure NO₂ in a variety of locations. Outdoor urban sites in Auckland dry and rural locations the Waikato Valley, New Zealand, were compared, with the seasonal variations of concentration showing a dependence on location. Samplers were also used to measure concentrations over vegetated surfaces, water and on the outside of a tall building. Vertical concentration gradients of NO₂ over grassed surfaces were detected, indicating deposition, however a similar phenomenon was not observed over water. Calculation of the deposition velocity of NO₂ from these data gave an unrealistic value which was most likely caused by windspeed effects or chemical reactions

Ullrich, D., 1997. Guideline and practical advice for the use of passive samplers to determine ambient air quality. Prepared for Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn, Germany, by Institute for Water, Soil and Air Hygiene of the Federal Environmental Agency, Berlin, Germany

Zhou, J., Smith, S., 1997. Measurement of ozone concentrations in ambient air using a badge-type passive monitor. *Journal of the Air & Waste Management Association* 47 (6), 697-703

Cocheo, V., Boaretto, C., Sacco, P., 1996. High uptake rate radial diffusive sampler suitable for both solvent and thermal desorption. *Am Ind Hyg Assoc J* 57, 897-904

Brauer, M., Brook, J.R., 1995. Personal and fixed-site ozone measurements with a passive sampler. *Journal of the Air & Waste Management Association* 45 (7), 529-537

Cortez-Lugo, M., Romieu, I., Palazuelos-Rendon, E., Hernandez-Avila, M., 1995. Evaluation of the validity and reproducibility of passive ozone monitors. *Salud publica de Mexico* 37 (3), 219-223

Jacob, J., Grimmer, G., Hildebrandt, A., 1995. The use of passive samplers for monitoring polycyclic aromatic hydrocarbons in ambient air. *Science of the Total Environment* 139-140, 307-322

Schjoerring, J.K., 1995. Long-term quantification of ammonia exchange between agricultural cropland and the atmosphere-I. Evaluation of a new method based on passive flux samplers in gradient configuration. *Atmospheric Environment* 29 (8), 885-893

Shooter, D., Watts, S.F., Hayes, A.J., 1995. A passive sampler for hydrogen sulfide. *Environmental Monitoring and Assessment* 38, 11-23

Brown, R.C., Wake, D., Thorpe, A., Hemingway, M.A., Roff, M.W., 1994. Preliminary assessment of a device for passive sampling of airborne particulate. *Annals of Occupational Hygiene* 38 (3), 303-318

Cao, X.L., Hewitt, C.N., 1994. An exposure system for the calibration of passive samplers to volatile organic compounds at low (ppbv) concentrations. *Journal of the Air & Waste Management Association* 44 (11), 1299-1302

Dillon, H.K., Gao, P., 1994. Laboratory evaluation of a novel reactive passive sampler for the quantitative determination of formaldehyde in air. *Journal of the American Industrial Hygiene Association* 55 (11), 1061-1068

Liu, L.J.S., Olson, M.P., III, Allen, G.A., Koutrakis, P., McDonnell, W.F., Gerrity, T.R., 1994. Evaluation of the Harvard Ozone Passive Sampler on human subjects indoors. Environ. Sci. Technol. 28 (5), 915-923.

Our study examined the performance of the Harvard ozone passive sampler, providing comprehensive evaluation results and investigation of ozone behavior around the human body through a series of chamber and indoor field tests. The results demonstrated excellent agreement between the passive and continuous measurements for both personal and indoor monitoring in an environmental exposure chamber. An ozone concentration gradient around the human body was found, most likely due to depletion and dilution effects. When the passive sampler was attached to a polystyrene backing plate and worn on the chest, ozone depletion on clothing was significantly reduced. Results from additional indoor field tests support those from the chamber study. The effective collection rate for personal samplers with backing placed on the chest was comparable for both chamber and field conditions, while the effective collection rate for microenvironmental samplers was lower in the field.

Schwar, M.J.R., 1994. A dust meter for measuring dust deposition and soiling of glossy surfaces. Clean Air 24 (4), 164-169

Tang, Y.Z., Fellin, P., Otson, R., 1993. Comparison of a charcoal tube and a passive sampling device for determination of low concentrations of styrene in air. In *Sampling and Analysis of Airborne Pollutants*, Winegar, E.D., Keith, L.H., editors. Lewis Publishers, Boca Raton, FL, pp. 79-90

Grosjean, D., Williams, E.L., 1992. A passive sampler for airborne formaldehyde. Atmospheric Environment Part A-General Topics 26 (16), 2923-2928.

A simple, inexpensive passive sampler is described that is capable of reliable measurements of formaldehyde at the parts per billion (ppb) levels relevant to indoor and outdoor air quality. The passive sampler consists of a modified dual filter holder in which the upper stage serves as the diffusion barrier, the lower stage includes a 2,4-dinitrophenylhydrazine (DNPH) -coated filter which collects formaldehyde, and the space between the two stages serves as the diffusion gap. The measured sampling rate, 18.8 ± 1.8 ml min⁻¹, was determined in experiments involving sampling of ppb levels of formaldehyde with the passive sampler and with DNPH-coated C18 cartridges and agrees well with the value of 19.4 ± 2.0 ml min⁻¹ calculated from theory. The measured sampling rate was independent of formaldehyde concentration (16-156 ppb) and sampling duration (1.5-72 h). The precision of the measurements for co-located passive samplers averaged 8.6% in purified and indoor air (office and museums) and 10.2% in photochemically polluted outdoor air. With a 1.2-μm pore size Teflon filter as the diffusion barrier, the detection limit is 32 ppb h, e.g. 4 ppb in an 8-h sample, 1.3 ppb in a 24-h sample, and so on. Perceived advantages and limitations of the sampler are discussed including flexibility, cost effectiveness and possible negative bias at high ambient levels of ozone

Grosjean, D., Hisham, M.W.M., 1992. A passive sampler for atmospheric ozone. Journal of the Air & Waste Management Association 42 (2), 169-173

Grosjean, D., Williams, E.L., II, 1992. Field tests of a passive sampler for atmospheric ozone at California mountain forest locations. Atmospheric Environment 26A (8), 1407-1411

Lee, K., Yanagisawa, Y., Spengler, J.D., Billick, I.H., 1992. Measurement of personal carbon monoxide exposures by mailed passive sampler. Journal of the Air & Waste Management Association 42 (9), 1212-1213

Hargreaves, K.J., Atkins, D.H.F., Bennett, S.L., 1991. The measurement of sulfur dioxide in the outdoor environment using passive diffusion tube samplers: A first report. Report No. AERE R12569. Harwell, UK

Hung, I.F., Liao, M.H., 1991. Aromatic hydrocarbons in indoor air. J. Environ. Sci. Health Part A A26 (4), 487-492.

Air was sampled for indoor and outdoor environment using 3M passive sampler. Among many volatile organic compounds present in the sample, seven were identified and quantified for evaluation. These compounds were found to be aromatic hydrocarbons and their concentrations in indoor and outdoor were found to be in the same order of magnitude with their I/O ratios very close to one. It was therefore concluded that outdoor source from vehicle emission was the major contributor to the presence of these aromatic hydrocarbons in indoor air

Krochmal, D., Gorski, L., 1991. Determination of nitrogen dioxide in ambient air by use of a passive sampling technique and triethanolamine as absorbent. Environmental Science & Technology 25 (3), 531-535.

The effects of temperature, humidity, and storage on a diffusive sampler were tested by use of the Amaya-Sugiura method, modified previously. Several materials were used as carriers for triethanolamine in the sampler. The mass of NO₂ absorbed in the sampler was determined spectrophotometrically as nitrite by using Saltzman solution. The collection efficiency of the sampler was lower than that calculated from Fick's law of diffusion due to significant contribution of liquid phase in the overall sampler diffusive resistance. This resulted in an increase of the mass of NO₂ absorbed in the sampler by ca. 20% per 10 °C of temperature growth and by ca. 25% when the relative humidity rose from 0 to 100%. Dependence of concentration of TEA solution in the sampler on the relative humidity of the air was noted. The relative precision of the method characterized by RSD was 10%; the detection limit of NO₂ was 10 µg/m³ for a 24-h exposure.

Cohen, M.A., Ryan, P.B., Yanagisawa, Y., Hammond, S.K., 1990. The validation of a passive sampler for indoor and outdoor concentrations of volatile organic compounds. *Journal of the Air & Waste Management Association* 40 (7), 993-997

Monn, C., Hangartner, M., 1990. Passive sampling of ozone. *Journal of the Air & Waste Management Association* 40 (3), 357-358

Saltzman, B.E., Caplan, P.E., 1989. Detector tubes, direct-reading passive badges and dosimeter tubes. In *Air Sampling Instruments for Evaluation of Atmospheric Contaminants*, 7 Edition, Hering, S.V., editor. American Conference of Governmental Industrial Hygienists, Cincinnati, OH, pp. 449-476

Shields, H.C., Weschler, C.J., 1987. Analysis of ambient concentrations of organic vapors with a passive sampler. *Journal of the Air Pollution Control Association* 37 (9), 1039-1045

Cassinelli, M.E., Hull, R.D., Cuendet, P.A., 1985. Performance of sulfur dioxide passive monitors. *Journal of the American Industrial Hygiene Association* 46 (10), 599-608

Levin, J.O., Andersson, K., Lindahl, R., Nilsson, C.A., 1985. Determination of sub-part-per-million levels of formaldehyde in air using active or passive sampling on 2,4-dinitrophenylhydrazine-coated glass fiber filters and high performance liquid chromatography. *Analytical Chemistry* 57, 1032-1035

McConnaughey, P.W., McKee, E.S., Pretts, I.M., 1985. Passive colorimetric dosimeter tubes for ammonia, carbon monoxide, carbon dioxide, hydrogen sulfide, nitrogen dioxide, and sulfur dioxide. *Journal of the American Industrial Hygiene Association* 46 (7), 357-362

McKee, E.S., McConnaughey, P.W., 1985. A passive, direct reading, length of stain dosimeter for ammonia. *Journal of the American Industrial Hygiene Association* 46 (8), 407-410

Posner, J.C., Moore, G., 1985. A thermodynamic treatment of passive monitors. *Am Ind Hyg Assoc J* 46 (5), 277-285

Sievering, H., Ton, N., 1985. A study of sulfate aerosol dry loading collection efficiency by passive samplers. *Journal of the Air Pollution Control Association* 35 (10), 1072-1074

Coutant, R.W., 1983. Evaluation of a passive monitor for volatile organics. Report No. EPA-600/S4-83-014. U.S. Environment Protection Agency, Environmental Monitoring Systems Laboratory, Research Triangle Park, NC

Douglas, K.E., Beaulieu, H.J., 1983. Field validation study of nitrogen dioxide passive samplers in a "diesel" haulage underground mine. *Journal of the American Industrial Hygiene Association* 44 (10), 774-778

Gonzalez, L.A., Sefton, M.V., 1983. Laboratory evaluation of stain length passive dosimeters for monitoring of vinyl chloride and ethylene oxide. *Journal of the American Industrial Hygiene Association* 46 (10), 591-598

Gonzalez, L.A., Sefton, M.V., 1983. Stain length passive dosimeter for monitoring carbon monoxide. *Journal of the American Industrial Hygiene Association* 44 (7), 514-520

Sefton, M.V., Kostas, A.V., Lombardi, C., 1982. Stain length passive dosimeters. Journal of the American Industrial Hygiene Association 43 (11), 820-824

Hill, R.H., Fraser, D.A., 1980. Passive dosimetry using detector tubes. Journal of the American Industrial Hygiene Association 41 (10), 721-729

Ghosh, A.K., Rajawar, D.P., Banerjee, N., 1973. Use of detector tubes for quality assessment and control of air pollutants - A critical review. Indian J. Environ. Hlth. 15 (2), 111-117

Palmes, E.D., Gunnison, A.F., 1973. Personal monitoring device for gaseous contaminants. Am Ind Hyg Assoc J 34, 78-81

Appendix II - A Summary Matrix of Peer-Reviewed Articles and Other Supporting Information on the Use of Passive Sampling Methods to Measure Air Quality. Compiled by Michael Kenney.

Summary Matrix of Peer-Reviewed Articles and Other Supporting Information on the Use of Passive Sampling Methods to Measure Air Quality

Author (lead)	Title	Year	Publication	Monitoring Technique	Pollutant(s) Monitored	Key Points
Batterman, S	Concentrations and emissions of gasoline and other vapors from residential vehicle garages	2006	Atmospheric Environment	thermal desorption, and GC-MS	VOC	Sample duration was 4-days in garages and outdoor air. Concentrations were strongly correlated to occupant activities.
Busbin, D.D.	A second look at the Palmes' diffusive sampler	2006	Journal of the Air & Waste Management Association	Palmes' tube diffusive sampler	Cyclohexane	Laboratory analysis shows a need to calibrate this type of sampler. The mass transfer resistance was nearly constant with perpendicular air flow.
Costabile, F.	A preliminary assessment of major air pollutants in the city of Suzhou, China	2006	Atmospheric Environment	diffusive sampling	NO2, NOx, SO2, and BTX	Predominate factors affecting frequency distribution of 100 sample locations included meteorology, emission sources, seasonality, and photochemistry.
Fan, Z.H.	Development of a passive sampler to measure personal exposure to gaseous PAHs in community settings	2006	Environmental Science & Technology	Fan-Lioy passive PAH sampler (FL-PPS)	PAH	Temperature, humidity, face velocity, and PAH concentration did not significantly affect the sampling rate. Agreement within 30% was obtained for most compounds as compared to a collocated active sampler.
Fiebig-Wittmaack, M.	A microscopic and chemical study of airborne coarse particles with particular reference to sea salt in Chile at 30 degrees	2006	Atmospheric Environment	passive sampling followed by microscopic single particle analysis and bulk ion chromatographic analysis	particulates	Sample duration was 1-week to determine source and transport of suspended particles
Giese, U.	Passive sampling	2006	Essential Air Monitoring Methods	various passive samplers	various	Among the topics discussed in this chapter include theory of passive sampling, types of samplers, and use of samplers.
Horton, A.	Personal monitoring of benzene in Perth, Western Australia: The contribution of sources to non-industrial personal exposure	2006	Atmospheric Environment	passive samplers	Benzene	Personal monitoring was conducted on 50 participants to determine exposure from non-industrial sources. Samplers were worn 24-hrs for 5 consecutive days in the summer and winter.
Lee, S.J.	Development and evaluation of personal respirable particulate sampler (PRPS)	2006	Atmospheric Environment	personal respirable particulate sampler (PRPS)	particulates and gaseous pollutants	The PRPS was compared to a collocated micro-orifice cascade impactor (MOI) and a real-time particle sizing instrument (SMPS/APS) in the lab and the PRPS measured size distribution was closer to the SMPS/APS than the MOI. In the field, the PRPS was also in very good agreement with a Harvard Impactor (HI), the USEPA PM2.5 Well Impactor Ninety Six (WINS), and a Harvard Personal Environmental Monitor (Harvard PEM).
Leith, D.	Passive Aerosol Sampler for PM10-2.5	2006	Presented at the AWMA Symposium on AQ Measurement Methods	Wagner-Leith passive aerosol sampler	PM	The sampler performance for measuring PM10-2.5 and determining elemental make-up and size distribution is discussed. Comparisons are also made to Federal Reference Method (FRM) samplers, which it did reasonably well.
Liu, G.Q.	Spatial distribution and seasonal variations of polycyclic aromatic hydrocarbons (PAHs) using semi-permeable membrane devices (SPMD) and pine needles in the Pearl River Delta, South China	2006	Atmospheric Environment	Semi-permeable membrane devices (SPMDs)	PAH	Used to determine spatial and seasonal distribution. Pine needles were analyzed for PAHs for comparison. Active air sampling (HiVol) was also conducted during the analysis period to calculate sampling rates for the SPMDs. Good agreement was found between the SPMDs and pine needles.
Smith, L.	Use of GIS and ancillary variables compound and nitrogen dioxide to predict volatile organic levels at unmonitored locations	2006	Atmospheric Environment	passive air sampling	NO2 & VOCs	Sampling was conducted at 22 schools to derive a predictive equation derived from regression. This was validated using two intensive monitoring sites. The independent variables found significant in predicting pollutants were elevation, population density, distance to a border crossing, distance to a petroleum facility, and traffic intensity (for NO2).

Summary Matrix of Peer-Reviewed Articles and Other Supporting Information on the Use of Passive Sampling Methods to Measure Air Quality

Author (lead)	Title	Year	Publication	Monitoring Technique	Pollutant(s) Monitored	Key Points
Thammakhet, C.	Cost effective passive sampling device for volatile organic compounds monitoring	2006	Atmospheric Environment	passive sampler	VOCs	System was calibrated by BTX standard gas and a linear regression coefficient of 0.99 was obtained and detection limits were determined. This method was implemented at 10 gas stations.
Wagner, J.	Passive Aerosol Sampler for Characterization, Ambient Concentration, and Particle Size Measurement	2006	Presented at the AWMA Symposium on AQ Measurement Methods	passive aerosol sampler	PM	Sampler theory and tests in workplace and residential environments are discussed. Comparison to active sampling have been fair to good, however passive sampling may be able to capture time and spatial exposure variability that an active sampler cannot.
Willis, B.	Evaluation of PM10, PM2.5 and PM10-2.5 Measurements using a Passive Particulate Sampler	2006	Presented at the AWMA Symposium on AQ Measurement Methods	Wagner-Leith passive aerosol sampler	PM	The performance of the sampler was evaluated in field studies against collocated Federal Reference Method (FRM) samplers using 1-week sample periods. The passive sampler agreed well with the collocated FRM samplers for PM10-2.5. Results for PM2.5 and PM10 indicate the need to improve on measuring fine fraction aerosol, but expected future improvements should enhance performance in this area. Coupled with CCSEM and x-ray spectrometry, the sampler will be capable of measuring the composition and size distribution of the ambient aerosol.
Bruno, P.	Reliability of a BTEX radial diffusive sampler for thermal desorption: Field measurements	2005	Atmospheric Environment	Radiello(R)--radial symmetry diffusive sampler	BTEX	Analysis was performed by thermal desorption and GC-MS. Test was conducted on blank values. Repeatability and sampling time influence was tested.
Bytnerowicz, A.	Passive sampler for monitoring ambient nitric acid (HNO3) and nitrous acid (HNO2) concentrations	2005	Atmospheric Environment	passive sampler	gaseous nitric acid (HNO3) and nitrous acid (HNO2)	The sampler is easy to make, inexpensive and resistant to harsh weather. The sampler has been calibrated against honeycomb denuder systems in outdoor air and in controlled exposures. It can measure wide ranges of concentrations and for extended periods.
Chatzis, C.	Indoor and outdoor personal exposure to benzene in Athens, Greece	2005	Science of the Total Environment	passive air samplers	Benzene	Fifty participates and their homes were monitored for six 5-day periods during a year. Wind speed largely determined exposure. Also important were time spent outdoors, means of transportation, and proximity to busy roads.
Farrar, N.J.	Field calibration of rapidly equilibrating thin film passive air samplers and their potential application for low-volume air sampling studies	2005	Environmental Science & Technology	Polymer-coated Glass (POG) samplers	PCBs	Testing showed the potential of POGs for extremely sensitive and dynamic passive air sampling.
Farrar, N.J.	Field deployment of thin film passive air samplers for persistent organic pollutants: A study in the urban atmospheric boundary layer	2005	Environmental Science & Technology	Polymer-coated Glass (POG) samplers	PCBs, PAHs, organochlorine pesticides	Outdoor measurements indicated the potential for rapid, low-volume sampling of ambient air.
Gerboles, M.	Modification of the Palmes diffusion tube and semi-empirical modeling of the uptake rate for monitoring nitrogen dioxide	2005	Atmospheric Environment	Palmes diffusion tube	NO2	The diffusion tube was modified to avoid the effect of wind turbulence and the volume of absorbent was optimized. The agreement between the modified Palmes tube and the chemiluminescence method was 5% of the mean bias. It fulfills the European Directive data quality objective of 25% accuracy and qualifies as a monitoring method for NO2.
Gonzalez-Flesca, N.	A new laboratory test chamber for the determination of diffusive sampler uptake rates	2005	Atmospheric Environment	Diffusive samplers	benzene, toluene, xylene, etc.	Lab test procedure to simulate various environmental conditions on uptake rate for different pollutants is described.
Gouin, T.	Variability of concentrations of polybrominated diphenyl ethers and polychlorinated biphenyls in air: implications for monitoring, modeling and control	2005	Atmospheric Environment	Passive air samplers	polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs)	Concentrations from the passive air samples agreed favorably with the high-volume air sampling data at outdoor locations.

Summary Matrix of Peer-Reviewed Articles and Other Supporting Information on the Use of Passive Sampling Methods to Measure Air Quality

Author (lead)	Title	Year	Publication	Monitoring Technique	Pollutant(s) Monitored	Key Points
Gouin, T.	Passive and active air samplers as complementary methods for investigating persistent organic pollutants in the Great Lakes basin	2005	Environmental Science & Technology	passive air samplers	organochlorine (OC) pesticides, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs)	Passive air samplers were compared against high-volume air sampling data. The comparison showed good agreement and suggests passive air samplers can provide cost-effective and complementary approach for monitoring the spatial and temporal trends of persistent organic pollutants.
Martin, N.A.	Measurements of environmental 1,3-butadiene with pumped and diffusive samplers using the sorbent Carbopack X	2005	Atmospheric Environment	Perkin-Elmer-type diffusive samplers with Carbopack X	1,3-butadiene	Seven day and 14-day uptake rates were determined for the sorbent material under a wide range of concentrations. There is indication that the sorbent may be useful in radial diffusive samplers for short-term monitoring.
Paschke, H.	New passive samplers for chlorinated semivolatile organic pollutants in ambient air	2005	Chemosphere	spiral-rod and a stir-bar passive sampler	SVOC	Advantages of these samplers are their simple design, low costs, and easy processing. A field trial was conducted with periodic determination of concentrations using low-volume sampling. The results show that the passive samplers are promising for the long-term air monitoring of SVOCs.
Pennequin-Cardinal, A.	Performances of the Radiello (R) diffusive sampler for BTEX measurements: Influence of environmental conditions and determination of modeled sampling rates	2005	Atmospheric Environment	Radiello (R) diffusive samplers	BTEX	Sampling rates were estimated under various controlled atmospheres to evaluate the performance of the Radiello sampler. The results for benzene conform to the future European 3 Directive for maximum uncertainty for annual concentrations near 5 ug/m3.
Pilidis, G.A.	BTX measurements in a medium-sized European city	2005	Atmospheric Environment	passive samplers	BTX	Passive and active samplers were used to measure BTX at several locations in a Greek city.
Pratt, G.C.	A field comparison of volatile organic compound measurements using passive organic vapor monitors and stainless steel canisters	2005	Environmental Science & Technology	passive diffusion-based organic vapor monitors (OVMs)	VOC	Field measurements were conducted using passive sampling and the US Federal Reference Method, which uses stainless steel canisters. The methods agreed best for BTEX. They were not in such good agreement for styrene and halogenated compounds. In most cases, the passive sampling underestimated relative to the canisters.
Soderstrom, H.	PAHs and nitrated PAHs in air of five European countries determined using SPMDs as passive samplers	2005	Atmospheric Environment	semipermeable membrane devices (SPMDs)	polycyclic aromatic hydrocarbons (PAHs) and nitro-PAHs	Passive sampling was conducted at 40 locations in five European countries during two 21-day sampling periods.
Strandberg, B.	Evaluation of two types of diffusive samplers and adsorbents for measuring 1,3-butadiene and benzene in air	2005	Atmospheric Environment	SKC-Ultra and Radiello diffusive samplers	1,3-butadiene and benzene	Two diffusive samplers were evaluated for monitoring over both long timescales and shorter periods. The two samplers were determined to be suitable both for stationary and personal monitoring of 1,3-butadiene and benzene, for the general population and for workplaces.
Sunesson, A.	Workplace and Ambient Air Monitoring of Benzene and 1,3-Butadiene Using Diffusive Sampling and Automatic Thermal Desorption	2005	Presented at the AIH Conference & Expo	Perkin Elmer ATD diffusive sampler with Carbopack X	benzene & 1,3-butadiene	Validation of the sampler was conducted for sampling periods of 30 minutes to a week. Uptake rates were determined in laboratory experiments for workplace and ambient air monitoring.
Van Drooge, B.L.	Passive sampling of atmospheric organochlorine compounds by SPMDs in a remote high mountain area	2005	Atmospheric Environment	Semi-permeable membrane devices (SPMDs)	hexachloro benzene (HCB) and polychlorobiphenyls (PCBs)	Measurements were conducted over 1.5 years and at various altitudes. The results were validated by comparison to active high-volume air sampling and the concentrations were in good agreement. These findings suggested that SPMDs can be useful monitoring systems for the atmospheric concentrations of organochlorine compounds in remote high mountain areas.
Bartkow, M.E.	Characterizing uptake kinetics of PAHs from the air using polyethylene-based passive air samplers of multiple surface area-to-volume ratios	2004	Environmental Science & Technology	passive sampling devices (PSDs)	PAHs	PSDs of different surface area to volume ratios were studied to characterize uptake kinetics of PAHs.
Bartkow, M.E.	Field-based evaluation of semipermeable membrane devices (SPMDs) as passive air samplers of polyaromatic hydrocarbons (PAHs)	2004	Atmospheric Environment	Semipermeable membrane devices (SPMDs)	SVOC	SPMDs were placed at two sites for 32 days in a metropolitan area. These were compared to concentrations from collocated HiVol samplers. The difference between the two sample methods were within a factor of 1.5.

Summary Matrix of Peer-Reviewed Articles and Other Supporting Information on the Use of Passive Sampling Methods to Measure Air Quality

Author (lead)	Title	Year	Publication	Monitoring Technique	Pollutant(s) Monitored	Key Points
Bertoni, G.	Measurement of long-term average carbon dioxide concentrations using passive diffusion sampling	2004	Atmospheric Environment	diffusive sampling	CO2	Indoor lab experiments show that this technique shows good precision and reproducibility, and is proposed as a suitable and inexpensive tool for monitoring urban and industrial sites and in indoor-outdoor studies.
Cruz, L.P.S.	A field evaluation of a SO2 passive sampler in tropical industrial and urban air	2004	Atmospheric Environment	Passive sampler	SO2	The passive sampler was exposed at different exposure periods in industrial and urban areas. Precision of three simultaneously applied samplers was 10%. Passive sampling, when compared to active monitoring methods, used in urban and industrial areas, showed an overall accuracy of 15%.
Perrino, C.	Development of a variable-path-length diffusive sampler for ammonia and evaluation of ammonia pollution in the urban area of Rome, Italy	2004	Atmospheric Environment	diffusive sampler	NH3	Polyethylene was found to be the best construction material and phosphorous acid was the best collecting medium. The device was able to operate in a wide loading range and reproducibility was better than 5%. Comparison with reference denuders showed good accuracy with a deviation less than 5%. The samplers were used to confirm the link between NH3 concentrations and traffic emissions.
Plaisance, H.	Response of a Palmes tube at various fluctuations of concentration in ambient air	2004	Atmospheric Environment	Palmes tube	not specified	Discusses theory of response to fluctuating concentrations. Although fast fluctuations of high amplitude induce temporal overestimations in the tube response, their contributions to the mean concentration estimated over the 14-day sampling time can be considered as negligible.
Sexton, K.	Evaluating differences between measured personal exposures to volatile organic compounds and concentrations in outdoor and indoor air	2004	Environmental Science & Technology	charcoal-based passive air samplers	VOC	Two day average concentrations were obtained for 14 VOCs in outdoor air of three urban neighborhoods, indoor air of participant's residences, and the breathing zone 71 adults over three seasons. Results showed that concentrations were highest for the breathing zone followed by indoor air and outdoor air.
Sexton, K.	Comparison of personal, indoor, and outdoor exposures to hazardous air pollutants in three urban communities	2004	Environmental Science & Technology	charcoal-based passive air samplers (3M model 3500 organic vapor monitors)	VOC	Two day average concentrations were obtained for 15 VOCs in outdoor air of three urban neighborhoods, indoor air of participant's residences, and the breathing zone 71 adults over three seasons. Results showed that concentrations were highest for the breathing zone followed by indoor air and outdoor air for 13 of the 15 VOCs. This indicates that ambient VOC measurements at monitoring sites can underestimate exposures for urban residents.
Singer, B.C.	Passive measurement of nitrogen oxides to assess traffic-related pollutant exposure for the East Bay Children's Respiratory Health Study	2004	Atmospheric Environment	passive samplers	NO2 & NOx	Weeklong measurements conducted over a 14 week span were conducted outside 10 schools and select student residences to examine traffic related pollution and children's health. Validation of the passive samplers showed a precision of better than 5% and agreed with collocated chemiluminescence measurements to within 8% for NO2 and 3% for NOx.
Soderstrom, H.S.	Passive air sampling using semipermeable membrane devices at different wind-speeds in situ calibrated by performance reference compounds	2004	Environmental Science & Technology	Semipermeable membrane devices (SPMDs)	PAH & PCB	Samplers were placed in a wind tunnel, protected and unprotected; outside the wind tunnel and outside the facility to determine if high wind speeds affected sampling rates over a 21-day sampling period. Concentrations were highest in samplers exposed to the highest wind speeds. The protected samplers in the wind tunnel reduced wind speed inside the device and thus the uptake and release rates.
van Pul, A.	Ammonia concentrations in the Netherlands: spatially detailed measurements and model calculations	2004	Atmospheric Environment	passive sampler	NH3	Concentrations were measured on a monthly basis at 159 outdoor locations, eight of which were located near a continuous monitoring station. The annual average concentrations at the monitoring stations were 18% higher than the passive samplers.
Son, B.	Volatile organic compounds concentrations in residential indoor and outdoor and its personal exposure in Korea	2003	Environment International	passive sampler	VOC	Twenty-four hour samples were conducted indoors and outdoors in a medium size city and a metropolitan city. Indoor/outdoor ratios of the targeted compounds ranged from 0.94 to 1.51.

Summary Matrix of Peer-Reviewed Articles and Other Supporting Information on the Use of Passive Sampling Methods to Measure Air Quality

Author (lead)	Title	Year	Publication	Monitoring Technique	Pollutant(s) Monitored	Key Points
Wagner, J.	Comparison of a passive aerosol sampler to size-selective pump samplers in indoor environments	2003	AIHA Journal	Wagner-Leith passive aerosol sampler	aerosols	The sampler was used to measure indoor air and was compared to active samplers. The data, combined with data from a previous study, showed a correlation coefficient of 0.96. The sampler was useful for obtaining aerosol size distributions and mass fractions. Limitations include increased sensitivity to contamination when fewer particles are collected, uncertainties in sampling semi-volatile particles, and the need for expertise and expense to analyze samples.
Liu, L.J.S.	Evaluation of media and derivatization chemistry for six aldehydes in a passive sampler	2001	Environmental Science & Technology	GMD passive sampler	aldehydes	The sampler was used over a 7-day period in population exposure studies. Results indicated that the GMD monitor is suitable for shorter-term sampling of formaldehyde and acetaldehyde but not acceptable for sampling of acetaldehyde, acrolein, crotonaldehyde, glyoxal, and methylglyoxal over a 7-d period due to the chemical reactions on the silica gel-impregnated cellulose pad coated with 2,4-dinitrophenylhydrazine (DNPH). However, a new formulation of the DNPH derivatization solution allows collecting the six target aldehydes over a 7-day sampling period.
Lohmann, R.	Further developments in the use of semipermeable membrane devices (SPMDs) as passive air samplers for persistent organic pollutants: Field application in a spatial survey of PCDD/Fs and PAHs	2001	Environmental Science & Technology	Semipermeable membrane devices (SPMDs)	polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs) & PAH	Samplers were located at 19 sites. Vapor phase species showed good reproducibility whereas particle phase species did not. High amounts were sequestered in SPMDs at sites where previous active monitoring has indicated high atmospheric concentrations, confirming the potential of SPMDs as a tool for semiquantitative spatial monitoring of atmospheric species.
US EPA	Fact Sheet, Air Toxics Monitoring: Overview	2001	Air Toxics Website	various	various	Among the topics discussed include how toxics monitors are located, how do air toxics monitors work (including passive sampling), and what methods are used to analyze air monitoring samples.
Varns, J.L.	Passive ozone network of Dallas: A modeling opportunity with community involvement	2001	Environmental Science & Technology	passive sampling devices	O3	Samplers are used at 30 sites in the DFW area to monitor ozone. The measurements showed high correlation with collocated continuous monitoring data [r range = 0.95 - 0.97].
Gillett, R.W.	Measurement of indoor formaldehyde concentrations with a passive sampler	2000	Environmental Science & Technology	Ferm type passive sampler	formaldehyde	The technique of determining concentration through high performance liquid chromatography has been validated against active sampling with close agreement. For this technique an exposure period of 3 days is equivalent to a limit of detection of formaldehyde of 3.4 ppbv and a limit of quantification of 7.6 ppbv.
NY DEC	Appendix C - Volatile Organics Monitoring Methods Comparison	2000	Bureau of Air Quality Surveillance website	Carbotrap 300 6628 adsorbent tubes	VOC	Overall, the comparisons between canister samples and tube samples were quite good. Most analytes were detected at levels below 0.5 ppbV and in most cases the adsorption tube showed lower levels than the canister results. This study and the resulting comparisons give the monitoring staff a very confident outlook on the change from the adsorbent based air sampling method to the canister based air sampling method.
Bernard, N.L.	Ozone measurement with passive samplers: Validation and use for ozone pollution assessment in Montpellier, France	1999	Environmental Science & Technology	Passive samplers	O3	Samplers were standardized using an O3 analyzer. Blanks and duplicates were tested to evaluated sensitivity and precision. They were validated by comparing on-site measurements with automatic UV absorption analyzers of the regional air quality network. The correlation coefficient was r = 0.9 and the regression coefficient was close to 1.
Chung, C.W.	Evaluation of a passive sampler for volatile organic compounds at ppb concentrations, varying temperatures, and humidities with 24-h exposures	1999	Environmental Science & Technology	3M 3520 organic vapor monitor (OVM)	VOC	Samplers were exposed to various known concentrations of specific VOC compounds at three different combinations of temperature and relative humidity. The results showed that samplers' performance was compound-specific and depended on concentration, temperature, and humidity.

Summary Matrix of Peer-Reviewed Articles and Other Supporting Information on the Use of Passive Sampling Methods to Measure Air Quality

Author (lead)	Title	Year	Publication	Monitoring Technique	Pollutant(s) Monitored	Key Points
Grosjean, D.	A passive sampler for airborne formaldehyde	1992	Atmospheric Environment	passive sampler	formaldehyde	A simple, inexpensive passive sampler is described that is capable of reliable measurements of formaldehyde at the ppb levels relevant to indoor and outdoor air quality. Perceived advantages and limitations of the sampler are discussed including flexibility, cost effectiveness and possible negative bias at high ambient levels of ozone.
Hung, I.F.	Aromatic hydrocarbons in indoor air	1991	J. Environ. Sci. Health	3M passive sampler	VOC	Sampling was conducted in both the indoor and outdoor environment. Seven aromatic hydrocarbons were among many VOCs present in the sample and the indoor/outdoor concentration ratios were close to one. The conclusion is that vehicle emissions is the major contributor of these compounds in indoor air.
AEA Energy & Environment	Non-Automatic Hydrocarbon Network		UK Air Quality Archive website	sorbent tubes containing Carbopack X	benzene & 1,3-butadiene	Thirty-five sites around the UK use sorbent tubes for monitoring benzene and 10 of these sites also monitor 1,3-butadiene. For benzene, air pumped through two tubes to produce two identical samples. For 1,3-butadiene, pairs of tubes sample the air passively.
Group of University of Edinburgh medical students	How is Air Pollution Monitored?		Air Pollution - The Real Truth (U. of Edinburgh website)	various	VOC	Contains brief description of passive, active and automatic sampling
IVL Swedish Environmental Research Institute	Brochure "Diffusive Samplers for Air Monitoring"		IVL website	IVL diffusive sampler	BTEX	IVL samplers are designed to avoid effects from wind, in-tube chemistry, temperature, humidity, and losses during storage.

Appendix III - Theory of Passive Samplers with an Illustrative Example- The Palmes Sampler for Nitrogen Dioxide (NO₂.)

Passive samplers operate by passive diffusion, which is well described by Fick's First Law:

$$F = -D \frac{\partial C}{\partial x}$$

where: F = the flux of material through a fixed cross-sectional area per unit time [nmol*cm⁻²*s]
D = the Diffusion constant for the compound being collected. For NO₂ diffusing through air, this has a value of 0.154 cm²*s⁻¹.
C= the concentration of the compound in air [?]. [For example: nmol NO₂ * (mol air)⁻¹ = ppb]
x= the length over which the concentration gradient is maintained. [cm]

Using the Palmes sampler for nitrogen dioxide as an example, we note that the amount of the compound (NO₂ [nmol]) passing through a given cross-sectional area, A [cm²], in a given amount of time, τ[s], is given by:

$$Amount \equiv FA\tau = -DA\tau \frac{\partial C}{\partial x}$$

In the Palmes sampler, the diffusion gradient is set up by the fact that NO₂ reacts quantitatively with the triethanolamine coated on the stainless steel screens at the base of the sampler. At this location, the concentration of NO₂ is, thus, zero. We assume that the concentration of NO₂ at the mouth of the tube is that found in the air, C_{air}. Assuming that the length of the tube is L [cm] and that the gradient is linear, to a high degree of accuracy, we can make the following assumption:

$$\frac{\partial C}{\partial x} \cong -\frac{C_{air}}{L}$$

Substitution gives:

$$Amount \equiv FA\tau = -DA\tau \frac{\partial C}{\partial x} = -DA\tau \left(-\frac{C_{air}}{L} \right)$$

For a fixed geometry tube, A/L is constant. Further, we can define the sampling rate, SR [cm³/s]=DA/L. This gives the simplified expression:

$$Amount = SR \tau C_{air}$$

A simple rearrangement affords determination of the concentration of NO₂ in the air during sampling as related to the Amount of material collected:

$$C_{air} = \frac{Amount}{SR \tau}$$

If we choose to measure concentrations in ppb, Amount in nmol, SR in nmol/hour and measure time in hours, the expression reduces to:

$$C_{air} [ppb] = \frac{Amount [nmol NO_2]}{SR [mol air sampled per hr] \tau [hr]} = \frac{Amount [nmol NO_2]}{\tau [hr] \bullet 0.00249 [mol air sampled per hr]} /$$

Palmer's formula is based on a temperature of 25 °C (77 °F). At 25 °C, assuming ideality, 1 ppb NO₂ = 1.881 µg NO₂/ m³.

Appendix IV- Passive Sampler for Logan Air Quality Monitoring Study- Samplers and Analytical Protocol

Samplers:

1. VOCs- BTEX and Other Compounds

Passive samplers for VOCs will be the OVM3500 series passive sampler typically used in occupational settings for eight-hour sampling. In our laboratory we have validated monitoring and analytical methods that afford sufficient sensitivity for two-day to three-week sampling using these devices. The devices are small, approximately 7 cm in diameter and 2 cm thick. They are robust and work well in community environments as long as they are protected from sunlight, wind, and rain/snow in an enclosure. See (Cohen, Ryan et al. 1990)

2. Aldehydes and Related Compounds

Passive sampling for the aldehydes formaldehyde, acetaldehyde, propionaldehyde, and acrolein will be accomplished using the Zhang sampler. These samplers absorb aldehydes using the hydrazine-hydrazone reaction commonly used for aldehyde sample collection. An alternative sorbent to dinitrophenylhydrazine, dansyl hydrazine, offers a significant improvement in sensitivity thus affording development of a passive sampler with sufficient sensitivity for our purposes. Dansyl hydrazine is coated on a C18 cartridge that then acts as the sampler itself. The samplers are small and unobtrusive with a barrel length of about 7 cm and a diameter of about 0.5 cm. They are robust and work well in community environments as long as they are protected from sunlight, wind, and rain/snow in an enclosure. See (Zhang, Zhang et al. 2000)

3. PAHs

Various PAHs can be collected using a passive sampling method developed by Fan and co-workers. This method uses standard gas chromatographic column material bundled together as an absorption medium. Approximately 320 1-cm sections of column are bound together in a holder for the collection of PAHs from air. The PAHs diffuse passively into the unobtrusive sampler, which is about 7 cm long, 2 cm wide, and 1 cm thick. They are robust and work well in community environments as long as they are protected from sunlight, wind, and rain/snow in an enclosure. See (Fan, Jung et al. 2006)

4. PM_{2.5}

A passive aerosol sampler consists of a miniature collection substrate housed in a protective cover with openings to the outside air. After exposure for an appropriate period of time, the sampler is returned to the laboratory where scanning electron microscopy (SEM) and automated image analysis are used to count and size collected particles. Image analysis is used in conjunction with particle density and shape factors to obtain the mass flux as a function of aerodynamic diameter. The mass flux and a deposition velocity model are then used to estimate the average mass concentration and size distribution over the sampling period. The deposition velocity model consists of a theoretical component and an empirical component. The theoretical component incorporates gravitational, inertial, and diffusive mechanisms, but can be approximated by the simple terminal settling velocity in many cases. While this is not an EPA reference method, it has been used in field studies and has been found to provide reliable results. See (Wagner, Leith 2001)

Analytical Protocols

1. VOCs- BTEX and Other Compounds

Analysis of this sample is effected through solvent extraction of the charcoal bed using carbon disulfide or similar solvent. After extraction, the extract is injected directly into the gas chromatograph injection port with no further work-up. Quantification is with a flame ionization detector. See (Cohen, Ryan et al. 1989; Cohen, Ryan et al. 1990; Cohen, Ryan et al. 1991)

Target Compounds- Benzene, toluene, ethylbenzene, xylenes, and other target VOC compounds as decided upon. Cannot collect or analyze for 1,3-butadiene.

2. Aldehydes and Related Compounds

Analysis of the various aldehydes is accomplished through solvent extraction of the derivatized carbonyl compound from the sorbent using acetonitrile and quantification using gradient high performance liquid chromatography and flurescence detection. See (Zhang, Zhang et al. 2000)

Target Compounds: formaldehyde, acetaldehyde, propionaldehyde, and acrolein. A few other aldehydes and acetone can be collected and analyzed for as well.

3. PAHs

Analysis of the samplers can be accomplished through solvent extraction and gas chromatographic analysis with a flame ionization detector, similar to that described under the VOC-BTEX samplers above. See (Fan, Jung et al. 2006)

Target compounds: The method has been tested for acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, and pyrene. More volatile PAHs such as naphthalene and the various methyl naphthlanes may be collected and analyzed for with varying degrees of success due to volatility. Final selected compounds are not yet decided.

4. PM_{2.5}

Analysis of the PM_{2.5} samples utilizes scanning electron microscopy and automated image analysis to count and size collected particles. The measured flux and a deposition velocity model are used to estimate the average mass concentration and size distribution over the sampling period. The deposition velocity model consists of a theoretical component and an empirical component. The theoretical component can be approximated by the simple terminal settling velocity in many cases. Target compound: Particulate matter with an equivalent aerodynamic diameter of 2.5 micrometers, consisting of numerous chemical constituents.

Appendix V - Brief Report on Nitrogen Dioxide Continuous Monitor/Palmes Sampler Collocation Sampling 29 Jun 2004- 27 Jul 2004.

For each one-week Palmes sampling period, I generated statistics for the Palmes samplers and for the continuous data with monitoring times as close as possible to those for the Palmes samplers. It is somewhat unfortunate, but there was not complete overlap for any of the four time periods.

The first table in the summary presents the results from the passive sampling program. Cycle represent the week sampled. Location identifiers were those given to me. On Date/On Time and Off Date/Off Time give the sampling duration. The measured concentrations are given in the two common units, ppb and $\mu\text{g}/\text{m}^3$. I assume 1.0 atmosphere of pressure (760 mm Hg) and 25 °C for the conversion.

The second table presents a series of statistical comparisons between the passive diffusion data and the integrated continuous monitoring data. I have included the following:

- 1. Average Cycle X**

Average of the four Palmes samplers for the monitoring period (nominally one week.)

- 2. Palmes StdDev**

Standard deviation of the four Palmes samplers. This is essentially a measure of the precision of the technique since the samplers are collocated. The second figure is the standard deviation of all samplers, including duplicates. This is expected to be higher due to phenomenon known as "regression to the mean." The third figure represents the average value of the percent difference between paired samples. This measure is strongly affected by even a single duplicate pair displaying a significant difference.

- 3. Continuous Average**

Average value for the continuous monitor for time periods most closely matching Palmes sampling period. Continuous values are taken every five minutes.

- 4. Continuous StdDev**

Standard deviation of continuous data. Unlike the Palmes StdDev, this value represents the minute by minute variability in NO_2 concentrations. A larger value indicates that the NO_2 concentrations are more "spikey" and thus may show significant differences at five minute intervals.

- 5. Relative Difference**

The difference between the Palmes results and the continuous average, divided by the mean of the two, presented as a percentage. Indicates relative error in Palmes results if the continuous is considered the "gold standard."

Notes: Discusses differences in sampling times.

Points of interest (some repeated from before):

- 1) Because of the physics involved in the collection process, the passive samplers cannot see very short-term spikes, say of duration less than about 15 minutes or so. Such peaks are heavily damped out resulting in underestimation of their contribution.
- 2) All four sampling locations were averaged to get the final results. The sampling strategy may have elected to place one or more of the sampling pairs away from the intake of the NO_x analyzer. If this is the case, a direct comparison should be made only with those samplers collocated with the NO_x inlet. However, in each of the four monitoring cycles, there was little difference among the four sets of samples- probably within the error of the technique.
- 3) Palmes samplers measure only NO₂. Comparisons with NO or NO_x are not valid.
- 4) The expected accuracy of Palmes samplers is +/- 20% nominal. I would expect that, due to point 2, the real term might be more like +15/-25% relative to a real-time analyzer.
- 5) The precision estimate is +/-10% nominal, measured as a standard deviation (68% of all samples should be within this limit). In this analysis, sample precision was somewhat better than the nominal value. However, inspection of the duplicate samples indicates higher value than the "variability" measure given in the Report. Looking now at paired Palmes samplers, one still can support the 10% precision estimate easily.
- 6) I did not report the absolute difference- this is easily seen by inspection and ranges from 0.7 ppb to 4.1 ppb. So, even though the relative error may be as high as 20%, the absolute error is quite low.

To summarize the results briefly, it appears that the passive samplers operate within the literature values of +/-10% precision and +/-20% accuracy, each as a standard deviation, if one makes the assumptions about collocation that I have made.

Site Name	On Date	On Time	Off Date	Off Time	Conc (ppb)	Conc (ug/m3)
Cycle 1 Location 1	06/29/04	12:30	07/06/04	13:10	21.6	40.7
Cycle 1 Location 2	06/29/04	12:33	07/06/04	13:17	21.2	39.9
Cycle 1 Location 3	06/29/04	12:37	07/06/04	13:25	20.6	38.8
Cycle 1 Location 4	06/29/04	12:40	07/06/04	13:31	20.0	37.5
Cycle 2 Location 1	07/06/04	13:12	07/13/04	16:48	16.2	30.4
Cycle 2 Location 2	07/06/04	13:20	07/13/04	16:56	15.4	28.9
Cycle 2 Location 3	07/06/04	13:26	07/13/04	17:01	14.7	27.6
Cycle 2 Location 4	07/06/04	13:32	07/13/04	17:08	15.2	28.6
Cycle 3 Location 1	07/13/04	16:50	07/20/04	14:55	17.1	32.1
Cycle 3 Location 2	07/13/04	16:59	07/20/04	15:01	17.2	32.4
Cycle 3 Location 3	07/13/04	17:02	07/20/04	15:05	17.1	32.1
Cycle 3 Location 4	07/13/04	17:10	07/20/04	15:09	16.8	31.6
Cycle 4 Location 1	07/20/04	14:59	07/27/04	17:28	15.1	28.3
Cycle 4 Location 2	07/20/04	15:03	07/27/04	17:30	15.4	29.0
Cycle 4 Location 3	07/20/04	15:07	07/27/04	17:31	14.9	28.1
Cycle 4 Location 4	07/20/04	15:11	07/27/04	17:32	14.9	28.1

Average Cycle 1 = 20.9 ppb **Palmer StdDev=** 3.5%/4.1%/4.1%
Continuous Average = 25.0 ppb **Continuous StdDev=** 15.9 ppb
Relative Difference (Palmer - Continuous) = -18.2%

Note: Times do not match exactly. Continuous analyzer ran from 6PM 29 Jun - 1PM on Jul 6.

Average Cycle 2 = 15.4 ppb **Palmer StdDev=** 4.0%/5.2%/6.5%
Continuous Average = 16.1 ppb **Continuous StdDev=** 10.6 ppb
Relative Difference (Palmer - Continuous) = -4.9%

Note: Times do not match exactly. Continuous analyzer ran from 2:24 PM 6 Jul - 4:14 on 11 Jul.

Average Cycle 3 = 17.1 ppb **Palmer StdDev=** 1.0%/2.4%/3.5%
Continuous Average = 18.2 ppb **Continuous StdDev=** 9.7 ppb
Relative Difference (Palmer - Continuous) = -6.7%

Note: Times do not match exactly. Continuous analyzer ran from 4:59 PM 13 Jul - 2:59 PM on 20 Jul.

Average Cycle 4 = 15.1 ppb **Palmer StdDev=** 1.6%/6.5%/10.8%
Continuous Average = 18.6 ppb **Continuous StdDev=** 13.9 ppb
Relative Difference (Palmer - Continuous) = -20.7%

Note: Times do not match exactly. Continuous analyzer ran from 3:04 PM 13 Jul - 9:09 AM on 20 Jul.

Appendix F
Response to MADEP and MADPH
Comments on Draft Air Quality
Work Plan

Appendix F

Response to MADEP and MADPH

Comments on Draft Air Quality Work Plan

This appendix provides responses to comments from the Massachusetts Department of Environmental Protection (MADEP) and the Massachusetts Department of Public Health (MADPH) on the Draft Air Quality Work Plan, dated February 2007. The comments were provided in a March 13, 2007 memorandum titled *Comments on Massport's Proposed Air Quality Monitoring Study, Draft Air Quality Work Plan Dated February 2007*. A copy of the memorandum is provided in the end of this appendix. Massport consulted with MADEP and MADPH on some of the technical issues presented in the Draft Work Plan over the last several months before the issuance of the Final Work Plan.

Presented below are the comments in bold followed by Massport's response to each comment.

General Comments

- G-1. Project Objectives – Redefine the objective of the monitoring program to make it clear that this study is will not [sic] constitute a before and after construction study. The Commonwealth's expert's do not believe that the detection of changes in air quality due to the Center Taxiway construction would be possible especially given the scope of the proposed study.**

We believe that the spirit of the MEPA directive and the best use of the resources available would be fulfilled by a community air quality baseline study most focused on toxic air pollutants that might typically be emitted from airport operations.

The language addressing objectives of the monitoring program has been modified to reduce the emphasis of the before and after monitoring of the construction of the Centerfield Taxiway. However, Massport is required, under the MEPA certificate, to collect baseline data for future studies. It is understood that the term baseline data is taken to mean the data collected before the implementation of the Centerfield Taxiway. The reference to future studies means the follow-up air monitoring after the implementation of the Centerfield Taxiway.

- G-2. We recognize your effort to be innovative (consistent with our past comments) to cover as much of the community as possible through the proposed extensive use of passive monitoring technology. However, we feel that the trace nature of ambient air toxics levels and the lengthy averaging time involved with passive samplers, will not yield sufficient resolution in the data for useful analysis. Moreover, although these samples can be co-located with the traditional active monitors, a much more robust database exists of**

active (the more traditional EPA recommended) monitoring method concentration results than those that might be obtained by the passive methods. For the most part, the collection of active monitoring methodologies contained in your proposal should be appropriate for measuring the trace levels of toxic air pollutants targeted by this study.

A white paper supporting the use of the passive monitors for ambient air quality monitoring studies is presented in Appendix E. The passive monitors will be co-located at the Primary sites (active monitors) for comparison between methods. Precision estimates will be made through the use of duplicate field samples, and quality control checks will include laboratory blanks and field blanks. Accuracy will be assessed by comparison of results with “gold standards” in a performance audit, where appropriate standards exist. Sensitivity, both in the sense of limit of detection (LOD) and the minimum difference between two samples will be assessed by evaluating calibration standards, blank variability, and duplicated differences. Further, these values will be compared with background values measured at both the MADEP Harrison Avenue and Lynn monitoring sites. This is further discussed in Appendix E.

In addition, the passive monitoring program provides spatial coverage of communities surrounding Logan Airport.

G-3. In order to characterize average conditions existing around the airport, time integrated, less highly time-resolved data than needed for source attribution is needed. The proposal has suggested that 24-hour average samples be actively collected during the first month of the monitoring program and for 2 months during peak aircraft activity. It is unclear whether the proposal is for collection on one day of that week or daily for the entire week of the month designated for sampling. We note a discordance between samples collected on a 7-day sampling period monthly and the one day in six cycle employed by MassDEP for its ambient air monitoring for VOCs, carbonyls and PM_{2.5}. We suggest that Massport present additional consideration of the scale and frequency of meteorological and airport activity events in relation to the two alternate sampling frequencies and then identify which might have the highest probability of capturing the events of interest.

Per consultation with MADEP the sampling schedule will occur on the U.S. Environmental Protection Agency (EPA) standardized monitoring schedule of once every 6th day for PM_{2.5} for the gravimetric sampling at one of the active monitoring locations. VOC and carbonyl samples will be collected on the same schedule dates, except samples will be collected once every 12th day at each of the Primary sites. Similarly, PM_{2.5} measurements at each of the Satellite sites using mini-vols will also be collected once every 12th day. Samples will be collected 12 consecutive months for both sampling periods for a total of approximately 30 samples per year. (See Figure 6-1 for an example sampling schedule).

The passive sampling schedule will incorporate one seven-consecutive-day period or longer each month, and the sampling period will be rotated forward in each consecutive month (See Figure 6-1). The correlating of passive samples collected on a seven-consecutive-day schedule compared to the VOCs and carbonyls collected once every 12th day schedule offer a data comparison challenge. The 12-day schedule is based on the EPA 6-day schedule, which is generally used to produce quarterly and year-long averages. Similarly, the 7-day or longer sampling schedule is used to provide an indication of longer-term upward and downward seasonal trends and an assessment of annual average concentrations. The Work Plan calls for an overlap of the passive monitoring schedule with the 24-hour, once-every-twelve day schedule to ensure that we are monitoring the same period. However, given the intent of both sampling schedules, namely to assess longer-term trends the comparison of only seasonally averaged data and annual average data will be performed.

Meteorological data will be collected at each of the Primary sites, and meteorological data generated at the National Weather Services (NWS) station at Logan Airport along with daily flight operations data will be retrieved from FAA and Massport. These data and the results of the first year of air quality monitoring data will be evaluated to modify the sampling plan to capture short-term peak events during the second year of monitoring.

- G-4. During planned sampling/monitoring events, representative, quality meteorological (wind speed, wind direction and temperature minimally) data should be collected to correlate results at monitoring locations. Also, specific activities and operations at the airport should be recorded for these sampling periods to be available as a component for data analysis.**

See response to comment no. G-3.

- G-5. The Departments would welcome efforts at determining the nature of emissions from airport operations. In line with the suggestion for innovative technology, we suggest that you investigate the utility of the laser technology for real-time ambient air measurements developed by Aerodyne Inc. to help characterize emissions from runway or other operations. Another suggestion would be to speciate TO14A canisters (taken from the sampling locations off site) for hydrocarbon fingerprints as an aid to explain odor complaints, which are regularly reported from neighborhoods adjacent to the airport.**

The use of laser technology for real-time measurements has not been widely used for airport air quality monitoring studies. The use of a U-V sampler for the Rhode Island Department of Environmental Management (RIDEM) study of T.F. Green Airport had limited success. In addition, the use of laser technology for measuring VOC concentrations from aircraft could also raise potential security issues.

Massport, in consultation with MADEP and MADPH agreed that based on the review of the first 12-months of monitoring results, meteorological data and Logan Airport flight operations data that it may be appropriate to conduct a set of short-term sampling

periods in addition to conducting a set sampling schedule during the second year of the monitoring program. The random sampling schedule would be conducted over the second consecutive 12-month period. Following such a schedule, which would be driven by empirical and changing conditions related primarily to the activity patterns of emission sources at the Airport, would attempt to capture short-term peaks of pollutant concentrations when they are expected to occur, such as those events that may cause odor complaints near the airport. If such an event is predicted, TO-15 sampling could be conducted to determine if there is a hydrocarbon fingerprint associated with jet fuel combustion.

- G-6. With less emphasis on satellite monitoring locations noted in your proposal for passive sampling, we recommend a program based on active monitors located in neighborhoods surrounding the airport. In order to obtain data on these neighborhoods and locations where air emissions are likely to be “worst” by virtue of proximity to the airport and juxtaposition with respect to predominant wind directions, we concur with a primary monitoring location in Winthrop off the north end of the runway. Would relocation of the proposed location at Massport at Annavoy to the Pleasant Park Yacht Club in Winthrop put the sampler(s) more directly in the downwind direction from the primary north/south runways and the new centerfield taxiway? We also suggest an active location at Cottage Street in Winthrop as it too is in proximity to the runway, taxiway waiting area , downwind from those locations and the area of past odor complaints. We also recommend adding a primary site in East Boston; possibly at the MassDEP Breman Street site.**

Per consultation with MADEP and MADPH and procedures used to evaluate the selection of monitoring locations presented in Section 5 of this Work Plan, three Primary sites (collocated active and passive monitoring) have been selected. These locations include Massport at Annavoy Street and MADEP Bremen Street in East Boston and Court Road in Winthrop. All three locations will also include passive monitoring equipment, in addition to the seven Satellite sites and one background site at the MADEP Harrison Avenue site.

- G-7. We also would like to have provision for analysis of the data collected be incorporated into the proposal.**

Section 9 provides the procedures to be implemented for analysis of the monitoring data.

- G-8. Given that the program will include 2 sampling rounds, we suggest that the results from the first round could be analyzed to identify any potential issues with data collection and remedy those issues in the second round.**

Massport agrees with this comment. This comment has been addressed in Section 9 of this Work Plan.

Specific Comments on Sampling Program

- S-1. From a monitoring objective perspective, we have to [sic] questions about the extent to which passive monitors are proposed. The proposed PM 2.5 Passive Method is not standard, given the amount of PM2.5 active sampling which has occurred across the country over the last 10 years. Also, the passive toxics samples will likely detect results near the minimum detection limits, where precision with other methodologies (like the active measurements) will not be too meaningful.**

The proposed passive PM2.5 sampling program has been replaced by the use of mini-vol samplers at all 11 sites per our discussions with MADEP and MADPH.

See response to comment G-2 regarding the use of passive samplers.

- S-2. The Massport proposal includes the operation of PM2.5 Beta Attenuation Monitors (BAMs) at the two active study sites, throughout the study period. Although the Massachusetts DEP has found them reliable for hourly averages for PM2.5, data for comparison to 24 hour and annual EPA Standards come from 24-hour FRM samplers. Although FRM samplers would not give the hourly resolution that the BAMS offer, they do yield data comparable to the standards and to a number of other locations in Massachusetts and Greater Boston. The proposal would be to operate the FRM samplers on the every third day EPA schedule, for the entire study year at the active sites, in tandem with the BAMs. A collocated sampler may be needed at one of the two locations for QC (precision) reasons. This proposal would be in lieu of the passive PM2.5 proposal. It should be noted that the BAM is an hourly method, not continuous or minute, as described by the Work Plan.**

The monitoring program will include the use of a U.S. EPA federal reference method (FRM) PM_{2.5} gravimetric sampler at one of the three Primary sites for comparison with the 24-hour and annual average National Ambient Air Quality Standards for PM_{2.5}. Sampling will be conducted once every 6th day to coincide with the EPA standardized sampling schedule. The BAM sampling frequency has been corrected to one-hour in Section 6 of this Work Plan.

- S-3. We have reservations about the passive PM2.5 Method proposed for this study. The method as described implies fairly dramatic size selection (gravity) prior to entry into the sampler. There may be assumptions about the PM2.5 fraction of the analyzed particles, which may not necessarily apply to the study area conditions.**

See response to comment no. S-1.

- S-4. It was mentioned during the last meeting that the passive PAH method had not been tested for naphthalene. It should be tested for naphthalene, because**

this compound is more volatile than many target PAHs, and is one of the environmentally important target compounds in this group.

The laboratory analysis of the PAH samples will include naphthalene.

- S-5. As long as the instruments are operated properly, we encourage the employment of both BAMs and Aethelometers (Black Carbon) at active sites.**

Massport agrees with this comment.

- S-6. The 24 hour VOCs and carbonyls run at Roxbury and Lynn year round, every sixth day. If these samples are operated during one seven day period per month for three months during the pre-study and two months during the post-study, how can the results can be compared properly to values found at the Roxbury and Lynn locations.**

See response to comment no. G-3.

- S-7. Massachusetts has had a site (Harrison Ave) nationwide NATTs (National Air Toxics Trends) network for several years. Over the last year or so, there have been extensive discussions about acrolein measurement, where it was determined that DNPH tubes (Method TO11) were not reliable for this compound, but that a modified TO15 (canister analysis for VOCs) was more acceptable. Method TO11 is used for Carbonyl Compounds and Acrolein appears on the Target Pollutant list (Table 4-1) categorized under the Carbonyl components.**

Desert Research Institute (DRI), the laboratory that will be analyzing the DNPH cartridges for carbonyl compounds, including acrolein, has developed a modified analytical method, proven in other sampling programs, to account quantitatively for acrolein. The modified method has been shown to quantify adequately both unrearranged acrolein captured on the DNPH medium and the rearranged acrolein-X which accumulates on the DNPH medium. On request, DRI can provide published studies demonstrating the efficiency of the modified analytical method for acrolein.

- S-8. QAPPs have been in the forefront of ambient air quality measurements recently. We request the opportunity to have a QA Officer for the DEP-AAB review the project QAPP, prior to the commencement of this study.**

Massport will provide copies of the draft QAPP to MADEP and MADPH for review.

MADEP and MADPH Comments Memorandum

MEMORANDUM

TO: Betty Desrosiers, Massachusetts Port Authority
FROM: Massachusetts Department of Environmental Protection
Massachusetts Department of Public Health
cc MassDEP: Barbara Kwetz, Tom McGrath, Christine
Kirby, Michael Hutcheson, Carol Rowan West
MADPH: Suzanne Condon, Margaret Round, Martha Steel, Meg
Blanchett,
Brian Glascock, City of Boston
DATE: March 13, 2007

RE: Comments on Massport's Proposed Air Quality Monitoring Study, Draft Air Quality Work Plan Dated February 2007

Thank you and your consultants for meeting with representatives from the Massachusetts Department of Public Health Center for Environmental Health (MDPH/CEH) and the Massachusetts Department of Environmental Protection on February 6, 2007 to discuss Massport's proposed "Air Quality Monitoring Study, Draft Air Quality Work Plan". This study is intended to meet the requirement for an air toxics monitoring program required in the 2001 Executive Office of Environmental Affairs (EOEA) Certificate on the Final Environmental Impact Report for the Logan Airside Improvements Planning Project. We appreciate the opportunity to provide comments on the proposal and convey the following suggestions for your review in advance of our next meeting together this coming Wednesday, March 14, 2007.

We have consulted with MEPA and others involved in the formative stages of the MEPA Certificate, as we have been concerned about the objectives, some of the proposed sampling/analytic methods and allocation of sampling effort in your proposal.

PROJECT OBJECTIVES

The Commonwealth would like Massport to redefine the objective of the monitoring program to make it clear that this study will not constitute a before and after construction study, as implied by the two part nature of the proposal, with the hiatus for construction in between. With the complexity of emission sources, located at and in the vicinity of the airport, the Commonwealth's experts do not believe that the detection of changes in air quality due to the Center Taxiway construction, would be possible, especially given the scope of the proposed study.

We believe that the spirit of the MEPA directive and the best use of the resources available would be fulfilled by a community air quality baseline study most focused on toxic air pollutants that might typically be emitted from airport operations.

MONITORING METHODS

We recognize your effort to be innovative (consistent with our past comments) to cover as much of the community as possible through the proposed extensive use of passive monitoring technology. However, we feel that the trace nature of ambient air toxics levels and the lengthy averaging time involved with passive samplers, will not yield sufficient resolution in the data for useful analysis. Moreover, although these samples can be co-located with the traditional active monitors, a much more robust database exists of active (the more traditional EPA recommended) monitoring method concentration results than those that might be obtained by the passive methods. For the most part, the collection of active monitoring methodologies contained in your proposal should be appropriate for measuring the trace levels of toxic air pollutants targeted by this study.

In order to characterize average conditions existing around the airport, time integrated, less highly time-resolved data than needed for source attribution is needed. The proposal has suggested that 24-hour average samples be actively collected during the first month of the monitoring program and for 2 months during peak aircraft activity. It is unclear whether the proposal is for collection on one day of that week or daily for the entire week of the month designated for sampling. We note a discordance between samples collected on a 7-day sampling period monthly and the one day in six cycle employed by MassDEP for its ambient air monitoring for VOCs, carbonyls and PM_{2.5}. We suggest that Massport present additional consideration of the scale and frequency of meteorological and airport activity events in relation to the two alternate sampling frequencies and then identify which might have the highest probability of capturing the events of interest.

During planned sampling/monitoring events, representative, quality meteorological (wind speed, wind direction and temperature minimally) data should be collected to correlate results at monitoring locations. Also, specific activities and operations at the airport should be recorded for these sampling periods to be available as a component for data analysis.

The Departments would welcome efforts at determining the nature of emissions from airport operations. In line with the suggestion for innovative technology, we suggest that you investigate the utility of the laser technology for real-time ambient air measurements developed by Aerodyne Inc. to help characterize emissions from runway or other operations. Another suggestion would be to speciate TO14A canisters (taken from the sampling locations off site) for hydrocarbon fingerprints as an aid to explain odor complaints, which are regularly reported from neighborhoods adjacent to the airport.

SAMPLING LOCATIONS

With less emphasis on satellite monitoring locations noted in your proposal for passive sampling, we recommend a program based on active monitors located in neighborhoods surrounding the airport. In order to obtain data on these neighborhoods and locations where air emissions are likely to be “worst” by virtue of proximity to the airport and juxtaposition with respect to predominant wind directions, we concur with a primary monitoring location in Winthrop off the north end of the runway. Would relocation of the proposed location at Massport at Annavoy to the Pleasant Park Yacht Club in

Winthrop put the sampler(s) more directly in the downwind direction from the primary north/south runways and the new centerfield taxiway? We also suggest an active location at Cottage Street in Winthrop as it too is in proximity to the runway, taxiway waiting area, downwind from those locations and the area of past odor complaints. We also recommend adding a primary site in East Boston; possibly at the MassDEP Breman Street site.

We also would like to have provision for analysis of the data collected be incorporated into the proposal.

Given that the program will include 2 sampling rounds, we suggest that the results from the first round could be analyzed to identify any potential issues with data collection and remedy those issues in the second round.

In summary, we are suggesting:

- a restatement of objectives to perform a baseline air quality monitoring study at two points in time;
- a focus on active sampling methods employing standard, validated methods;
- use of several primary active sampling monitoring stations located in surrounding neighborhoods potentially influenced by emissions of particles and chemicals from Logan Airport's activities.
- See the attached specific technical comments on the proposal.

We look forward to discussing these issues with you at our upcoming meeting.

Specific Comments on Proposed Air Sampling Methods

1. From a monitoring objective perspective, we have to questions about the extent to which passive monitors are proposed. The proposed PM 2.5 Passive Method is not standard, given the amount of PM2.5 active sampling which has occurred across the country over the last 10 years. Also, the passive toxics samples will likely detect results near the minimum detection limits, where precision with other methodologies (like the active measurements) will not be too meaningful.
2. The Massport proposal includes the operation of PM2.5 Beta Attenuation Monitors (BAMs) at the two active study sites, throughout the study period. Although the Massachusetts DEP has found them reliable for hourly averages for PM2.5, data for comparison to 24 hour and annual EPA Standards come from 24-hour FRM samplers. Although FRM samplers would not give the hourly resolution that the BAMS offer, they do yield data comparable to the standards and to a number of other locations in Massachusetts and Greater Boston. The proposal would be to operate the FRM samplers on the every third day EPA schedule, for the entire study year at the active sites, in tandem with the BAMs. A collocated sampler may be needed at one of the two locations for QC (precision) reasons. This proposal would be in lieu of the passive PM2.5 proposal. It should be noted that the BAM is an hourly method, not continuous or minute, as described by the Work Plan.
3. We have reservations about the passive PM2.5 Method proposed for this study. The method as described implies fairly dramatic size selection (gravity) prior to entry into the sampler. There may be assumptions about the PM2.5 fraction of the analyzed particles, which may not necessarily apply to the study area conditions.
4. It was mentioned during the last meeting that the passive PAH method had not been tested for naphthalene. It should be tested for naphthalene, because this compound is more volatile than many target PAHs, and is one of the environmentally important target compounds in this group.
5. As long as the instruments are operated properly, we encourage the employment of both BAMs and Aethelometers (Black Carbon) at active sites.
6. 24 hour VOCs and Carbonyls run at Roxbury and Lynn year round, every sixth day. If these samples are operated during one seven day period per month for three months during the pre-study and two months during the post-study, how can the results can be compared properly to values found at the Roxbury and Lynn locations.
7. Massachusetts has had a site (Harrison Ave) nationwide NATTs (National Air Toxics Trends) network for several years. Over the last year or so, there have been extensive discussions about acrolein measurement, where it was determined that DNPH tubes (Method TO11) were not reliable for this compound, but that a

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